IMRT /IGRT /Radiosurgery/SBRT : Clinical Aspects

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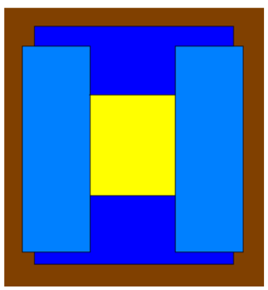
The Evolution of Radiation Therapy

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

1960’s

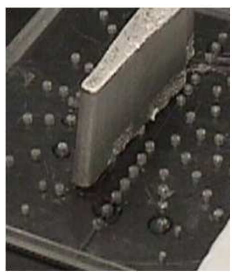
The First Clinac



Standard Collimator

The linac reduced complications compared to Co60

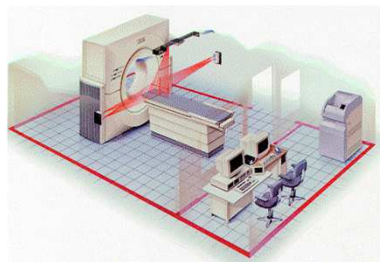
1970’s



Cerrobend Blocking
Electron Blocking

Blocks were used to reduce the dose to normal tissues

1980’s

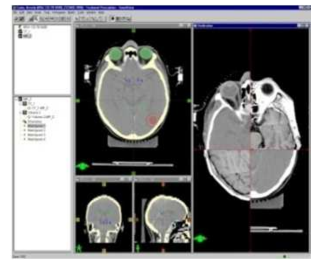


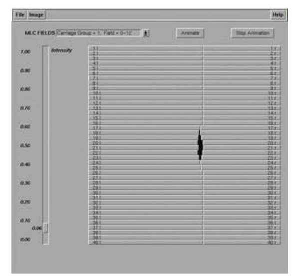
Multileaf Collimator

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

Computerized 3D CT Treatment Planning

1990’s

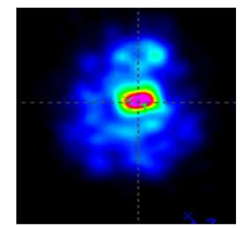




Dynamic MLC and IMRT

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

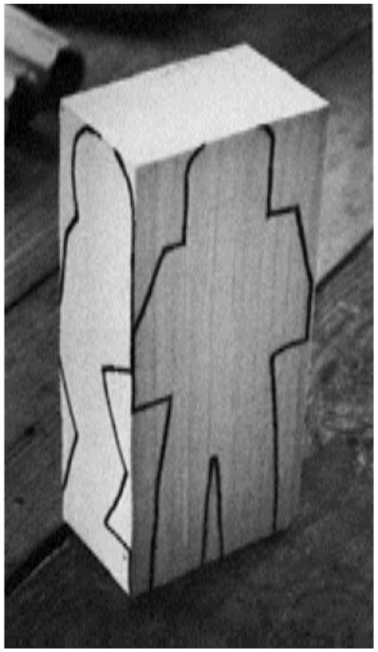
PARADIGM SHIFTS IN MANAGEMENT

Advances in Radiotherapy

Physical
- Better Physical and biological imaging
- Improvements in planning
- Improvements in treatment delivery

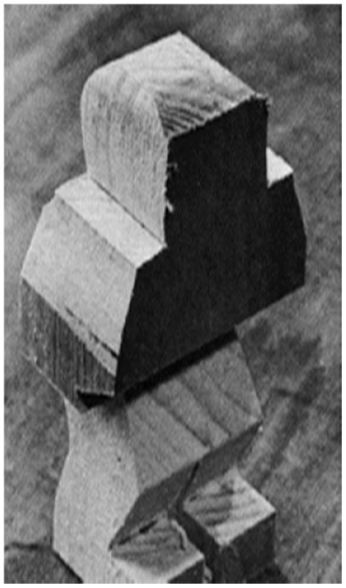
Biological
- Altered fractionation
-

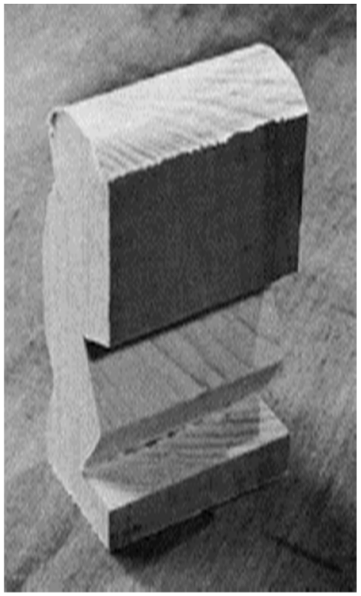
Improvement in survival and quality of life



2D

3 D



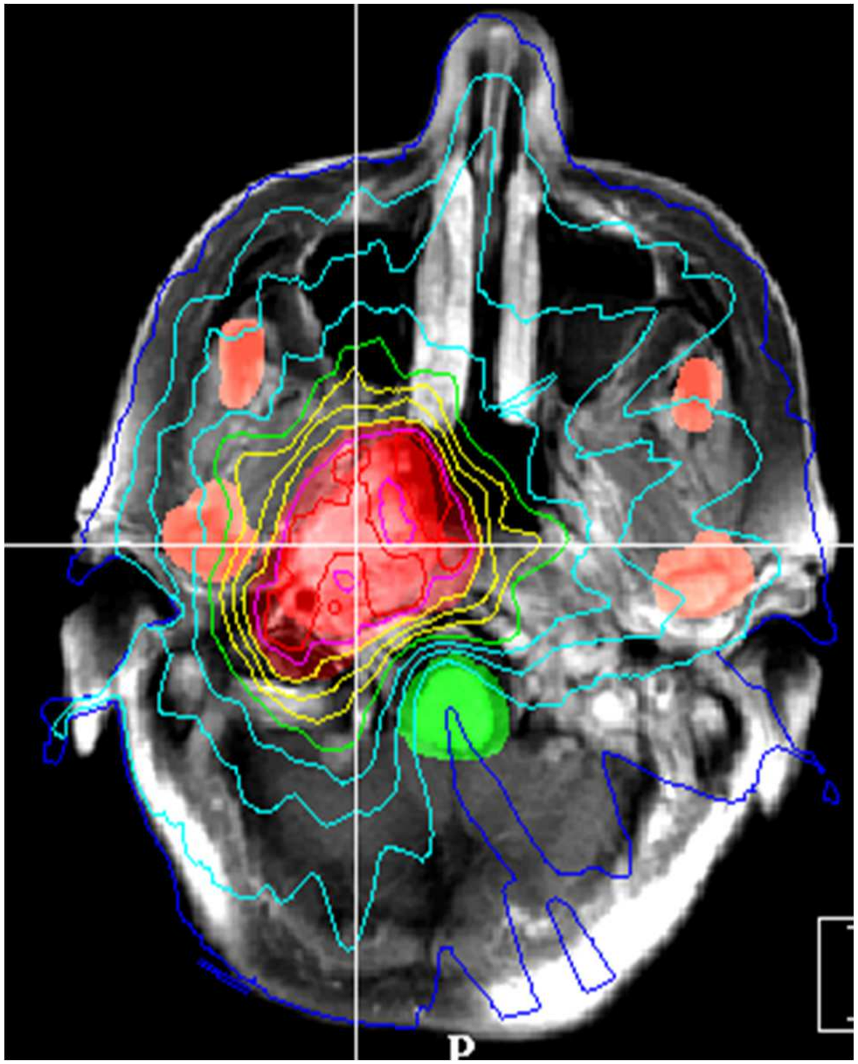


2D Shaped

IMRT

CONFORMAL THERAPY

It is described as radiotherapy treatment that creates a high dose volume that is shaped to closely " Conform" to the desired target volumes while minimizing the dose to critical normal tissues.



Features of Conformal Radiotherapy

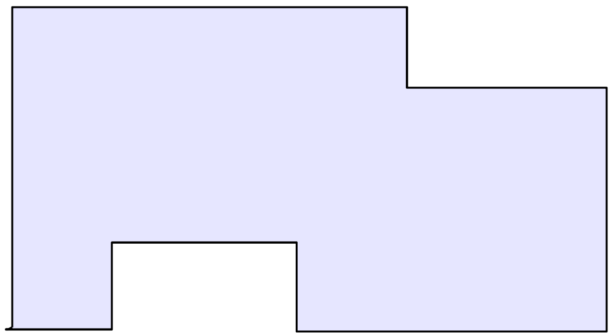
1)Target volumes are defined in three dimensions using contours from a volumetric imaging modality

2)Multiple beam directions are used to crossfire on the targets.

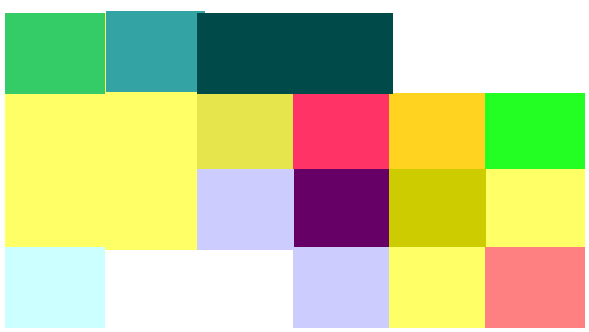
3)Individual beams are shaped or intensity modulated to create a dose distribution that conforms to the target volume and desired dose levels.

4)Use of image guidance,accurate patient setup ,immobilization and management of motion to ensure accurate delivery of the planned dose distributions to the patient.

Types of Conformal Radiation

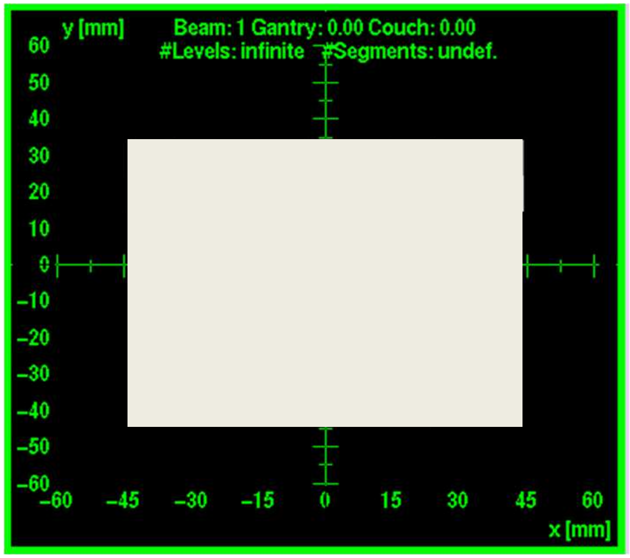


Geometrical Field shaping



Geometrical Field shaping with Intesity Modulation

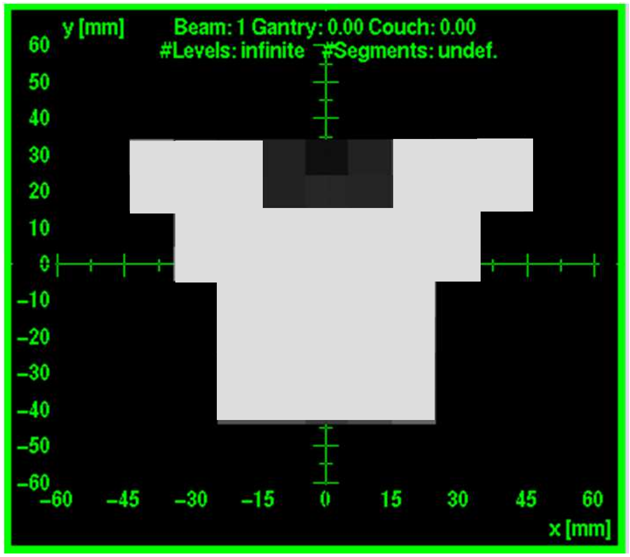
- Two broad subtypes :
  - Techniques aiming to employ geometric field shaping alone(3D-CRT)
  - Techniques to modulate the intensity of fluence across the geometrically-shaped field (IMRT)



Conventional RT Beam

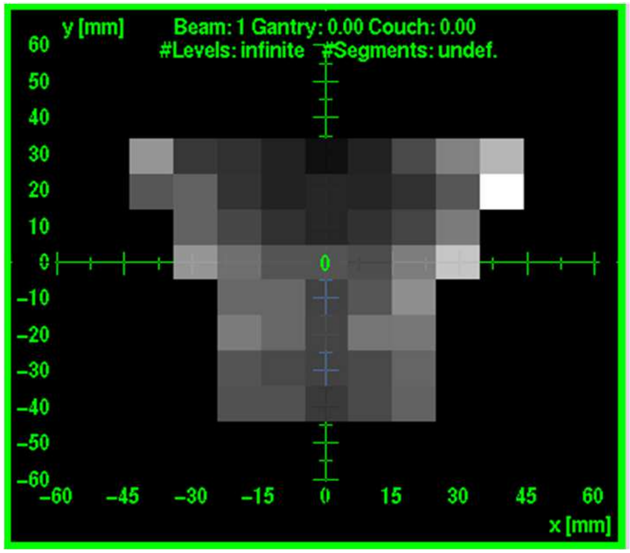
Uniform Beam Intensity

squares / rectangles



Conformal RT Beam

Uniform Beam Intensity



IMRT Beam

Non-Uniform Beam Intensity

WHAT IS 3-D CRT

To plan & deliver treatment based on 3D anatomic information. such that resultant dose distribution conforms to the target volume closely in terms of

Adequate dose to tumor &

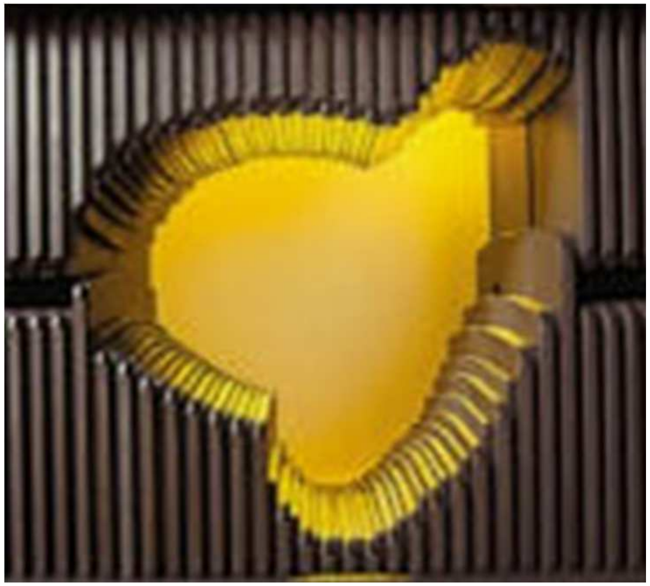
Minimum dose to normal tissues.

The 3D CRT plans generally

use increased number of radiation beams

to improve dose conformation and conventional beam modifiers (e.g., wedges and/or compensating filters) are used.

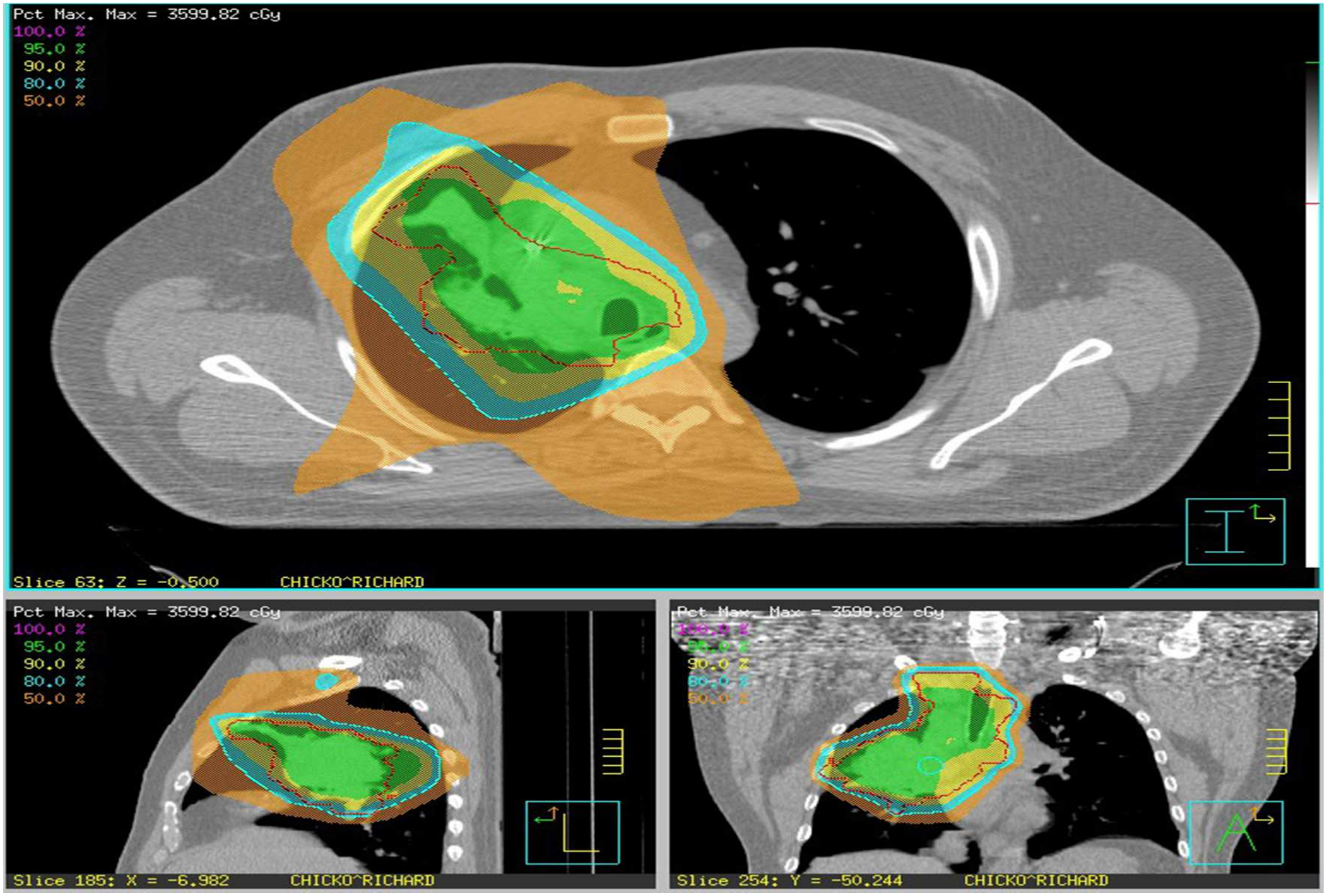
3D-CRT



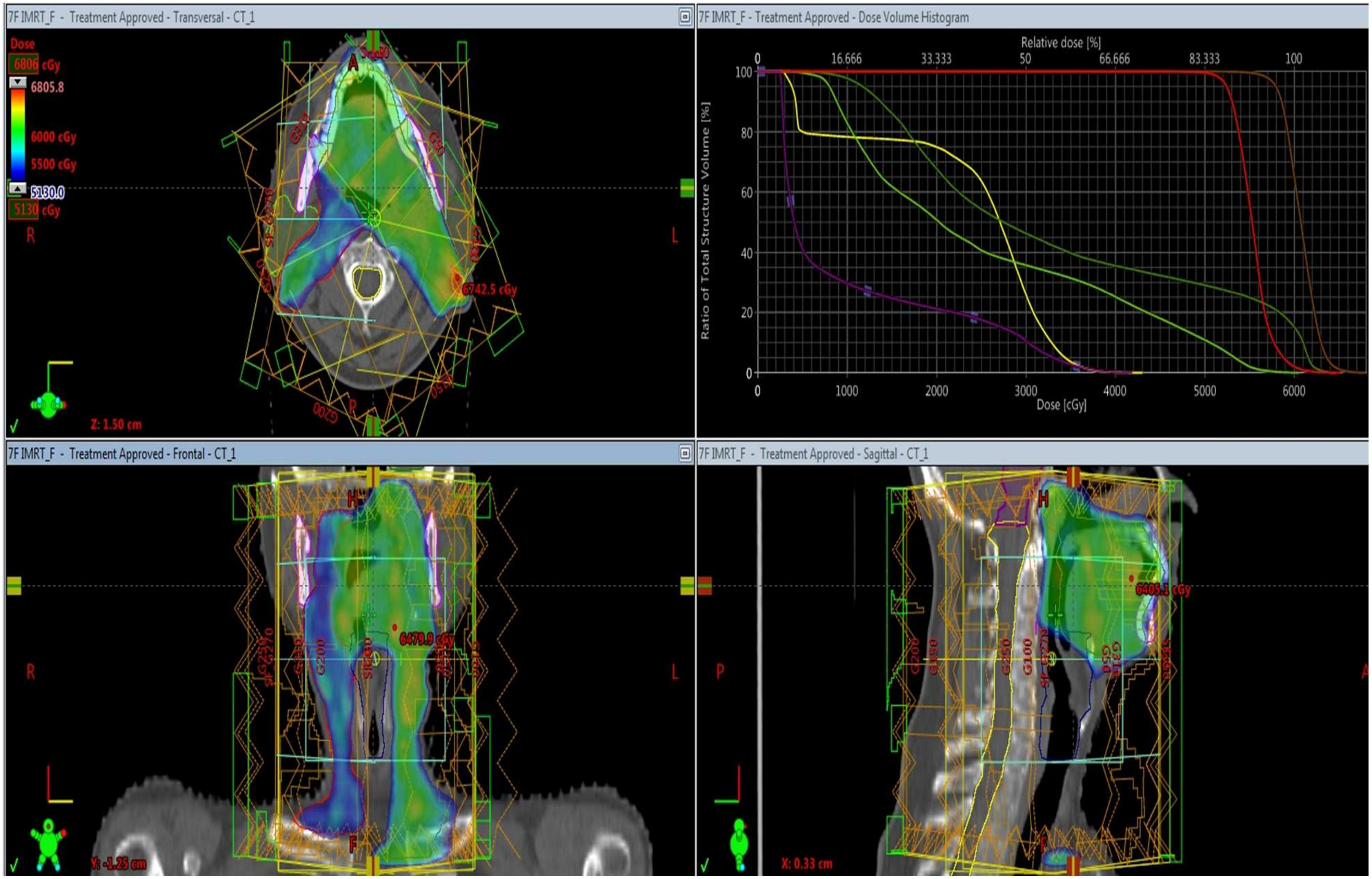
1. Radiation intensity is uniform within each beam

2. Modulation conferred only by Beam modifiers and shapers

3D conformal radiation therapy
Full 3D CT dataset, ICRU 50,62 definition of target and OAR volumes



3 DCRT – Head & Neck



Intensity modulated radiotherapy (IMRT)

IMRT is an advanced form of 3D CRT

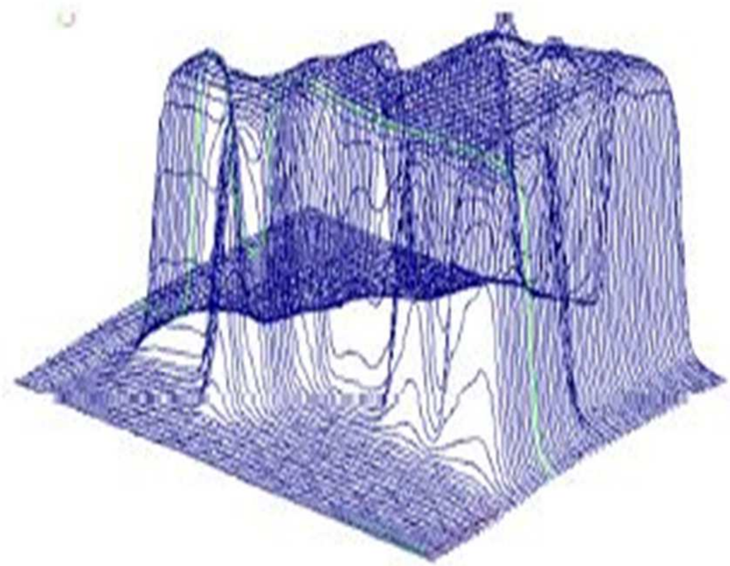
IMRT refers to a radiation therapy technique in which

nonuniform fluence is delivered to the patient from any given position of the treatment beam

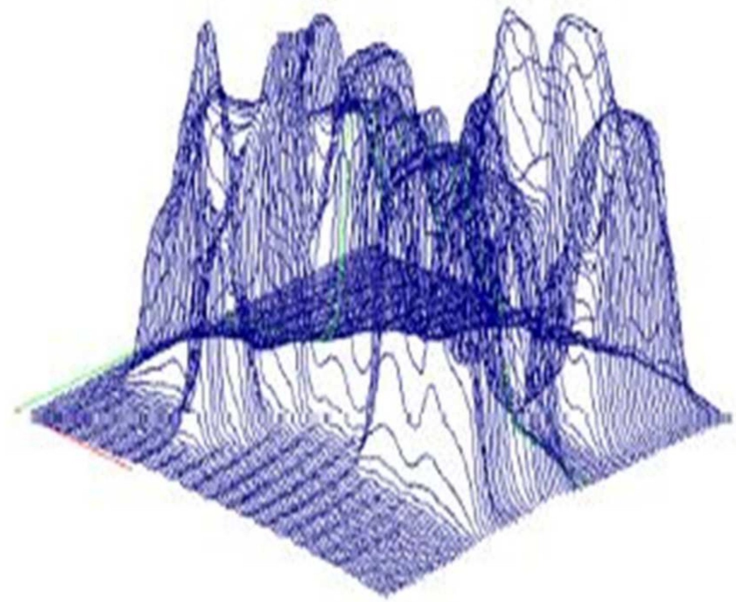
using computer-aided optimization to attain certain specified dosimetric and clinical objectives.

Transition from 3DCRT to IMRT

3-D conformal radiotherapy without intensity modulation



Intensity-modulated radiotherapy



IMRT RATIONALE

More conformal than 3D CRT

A sharp fall off PTV boundary

Reduction of normal tissue dose

To create concave isodose surfaces or
low-dose areas surrounded by high dose.

Lower rate of complication-lower cost of
patient care following treatment

Large fields and boosts can be integrated
in single treatment plan

Radiobiologic advantage

Divides each treatment field into multiple segments upto (500/angle)

Allows dose escalation to most aggressive tumor cells; best protection of healthy tissue

Modulates radiation intensity; gives distinct dose to each segment

Uses 9+ beam angles, thousands of segments

Improves precision/accuracy

Requires inverse treatment planning software to calculate dose distribution

LIMITATIONS OF IMRT

Many dose distributions physically not achievable

Interfraction variation

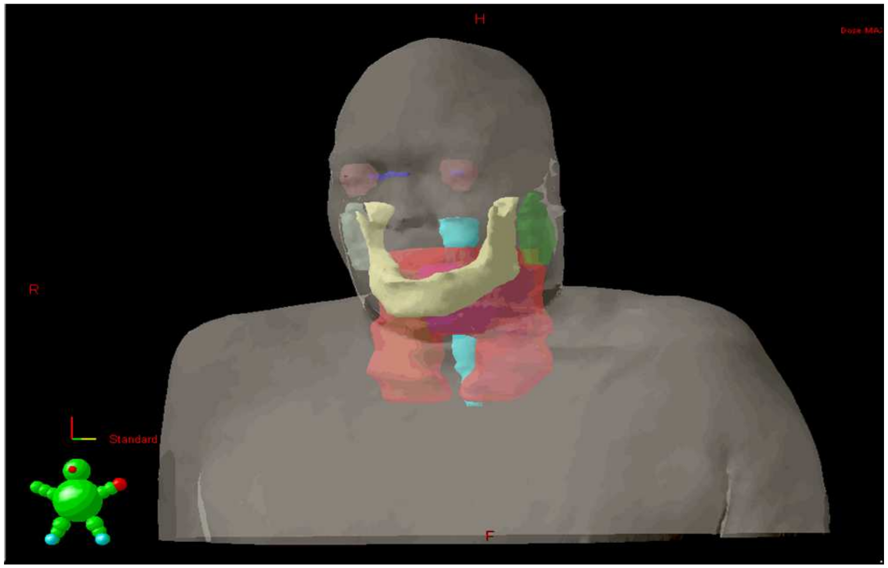
Positioning

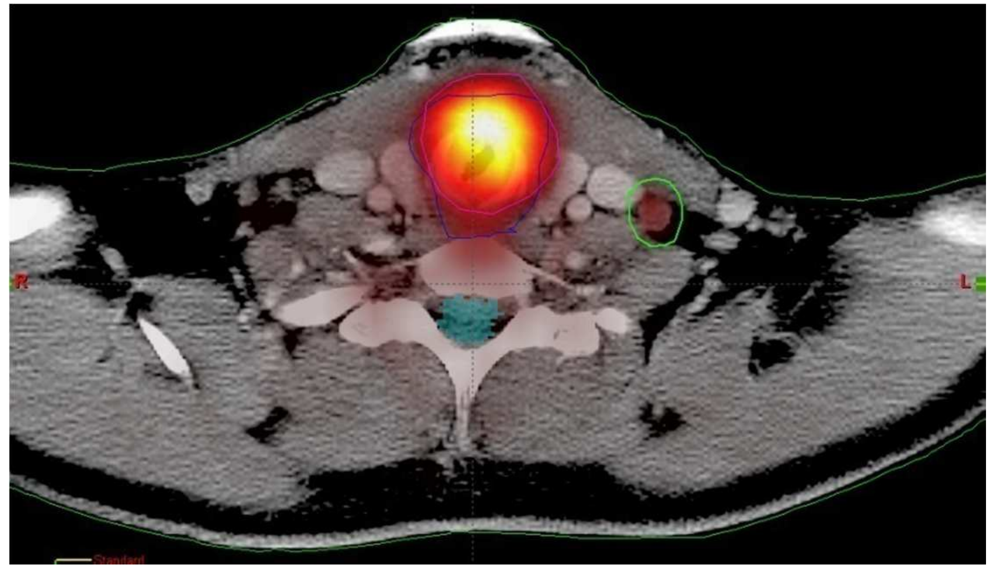
Displacement and distortion of internal anatomy

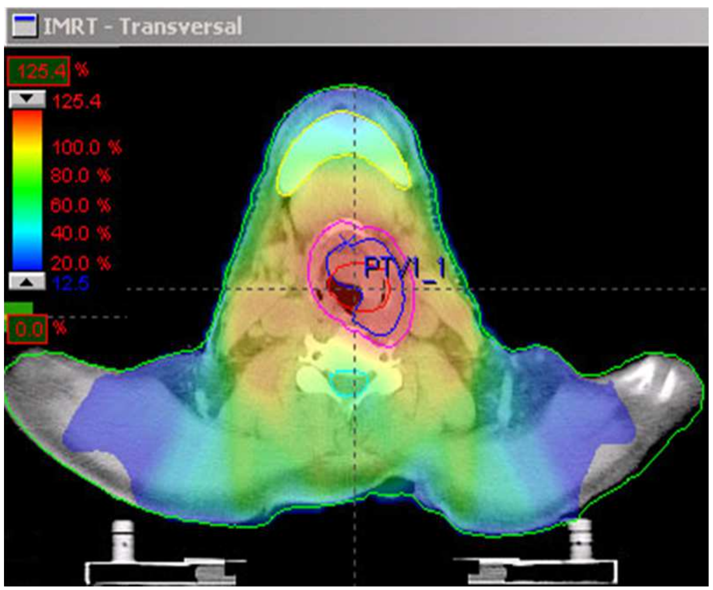
Intrafraction motion

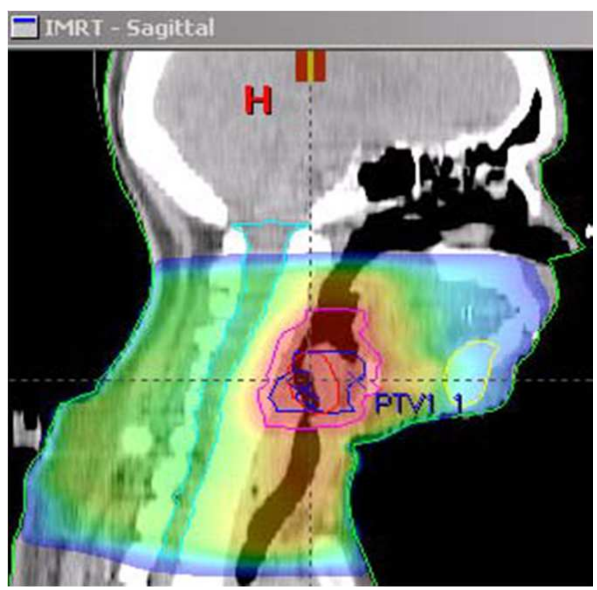
Changes of physical and radiobiologic characteristic of tumor and normal tissue

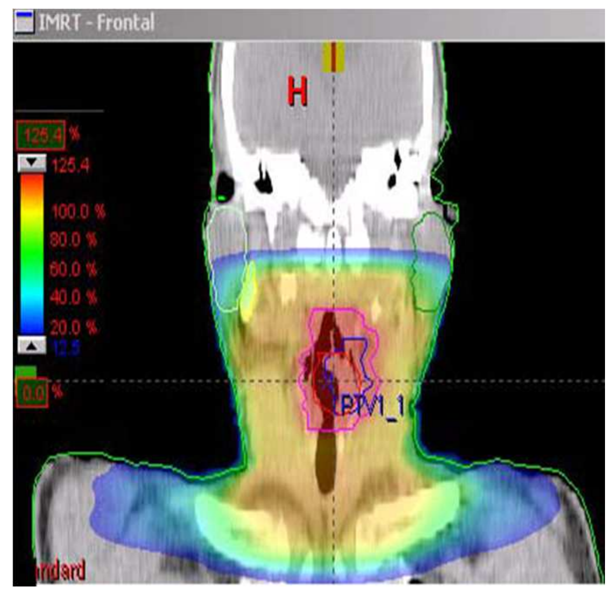
IMRT-Full 3D CT dataset; ICRU 50,62 definition of target and OAR volumes; co-registration of PET and CT images



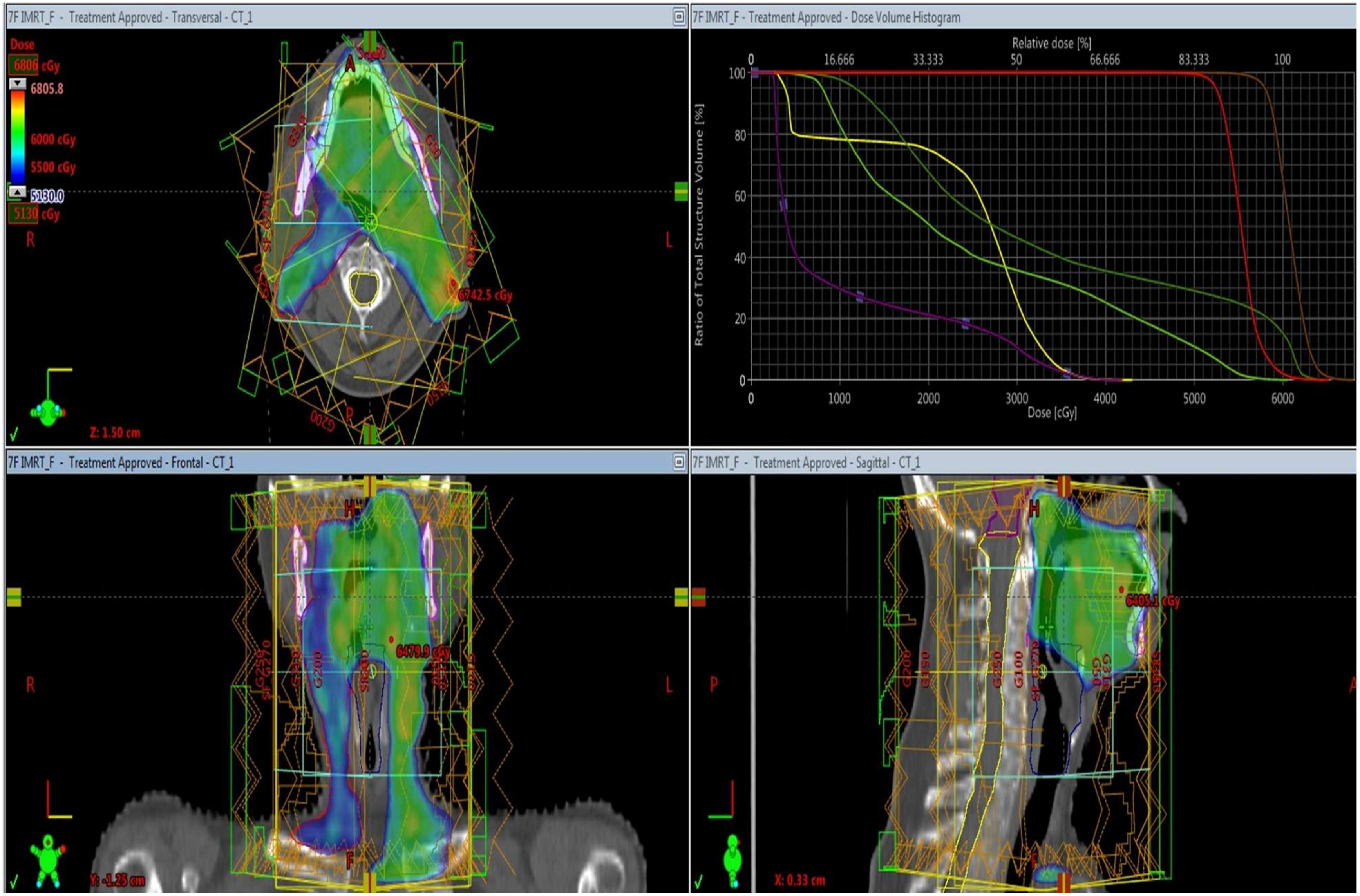








IMRT – Head & Neck



IMRT DELIVERY

- Having calculated the fluence distributions or fluence maps for each field angle, one now needs to have a means of delivering those fluence maps.
- Methods to deliver an IMRT treatment are:
  - Compensator based IMRT
  - Multileaf collimator (MLC) based
    - Static or step & shoot mode
    - Dynamic mode
  - Intensity modulated arc therapy (IMAT)
  - Tomotherapy

COMPENSATOR BASED IMRT

- compensators are used to modulate intensity.
- compensators must be constructed for each gantry position employed and then placed in the beam for each treatment.
- Adv. of physical attenuators are
  - Highest MU efficiency
  - Devoid of problems such as
    - leaf positioning accuracy,
    - interleaf leakage and
    - intraleaf transmission,
    - rounded leaf, and
    - tongue-and-groove effect that are intrinsic to MLC systems.

Fig. 1. How a compensator was constructed from thin lead sheets glued together in order to modulate the intensity of a tangential beam for improving the homogeneity of dose in breast radiation therapy (Courtesy of the Breast Technology Group, Royal Marsden NHS Foundation Trust)

- Disadv of physical attenuators
  - issues related to material choice, machining accuracy, and placement accuracy.
  - Labour intensive as each field has unique intensity map & requires separate compensator.

STEP & SHOOT IMRT

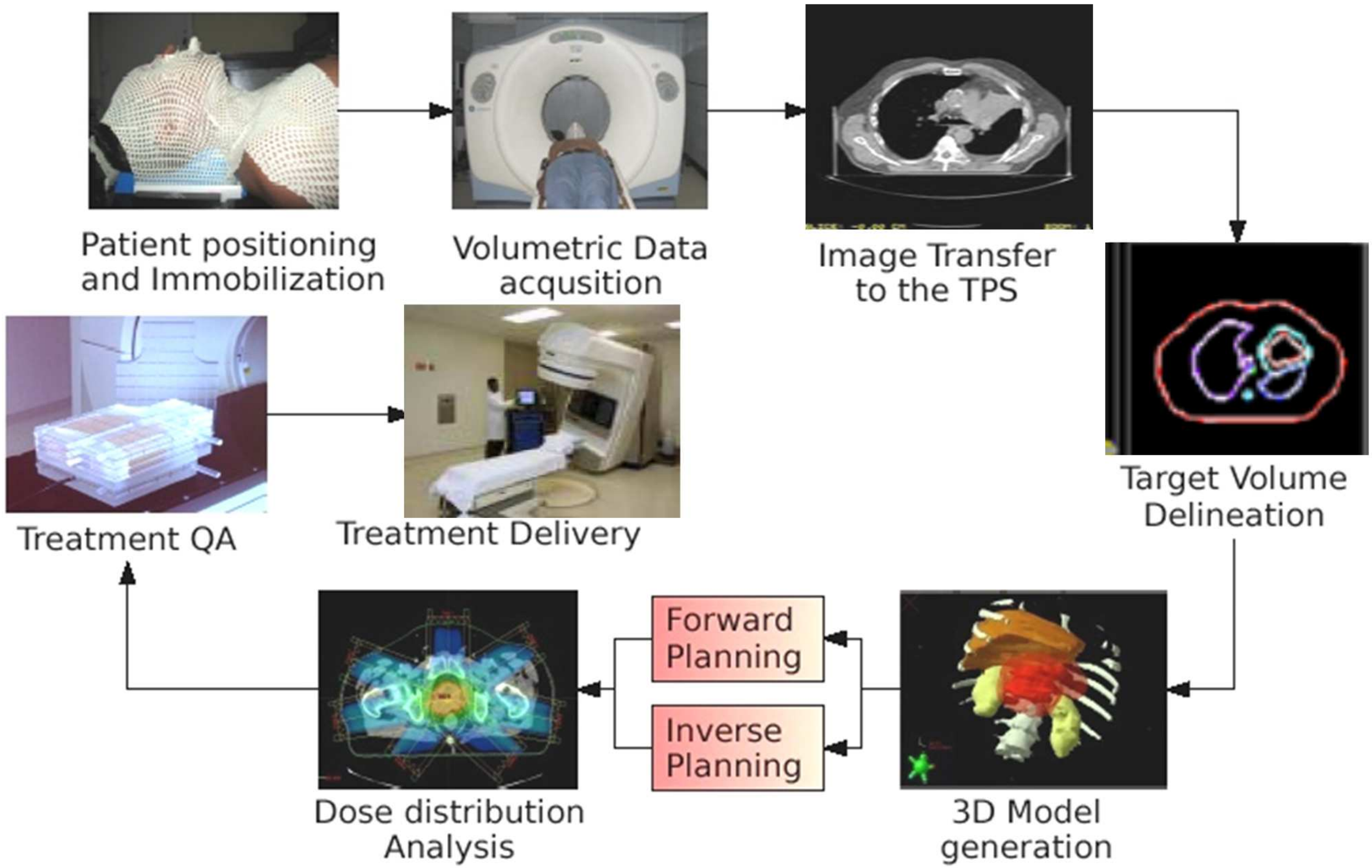
- In static or step & shoot mode the intensity modulated fields are delivered with a sequence of small segments or subfields, each subfield with a uniform intensity.
- The beam is only turned on when the MLC leaves are stationary in each of the prescribed subfield positions.
- Adv. of SMLC
  - Simple concept resembles conventional treatment
  - Easy to plan, deliver & to verify
  - an interrupted treatment is easy to resume
  - fewer MUs in comparison to DMLC
  - less demanding in terms of QA
- Disadv. of SMLC
  - Slow dose delivery (5 min/field)
  - Hard on MLC hardware

DYNAMIC MODE

- In the DMLC or sliding window mode, the leaves of MLC are moving during irradiation i.e. each pair of opposing leaf sweeps across target volume under computer control.

- Adv. Of DMLC
  - Better dose homogeneity for target volumes
  - Shorter treatment time for complex IM beams
- Disadv of DMLC
  - More demanding in terms of QA
    - leaf position (gap), leaf speed need to be checked
  - Beam remains on throughout – leakage radiation increased
  - Total MU required is more than that for SMLC
    - increased leakage dose

WORKFLOW OF CONFORMAL RT



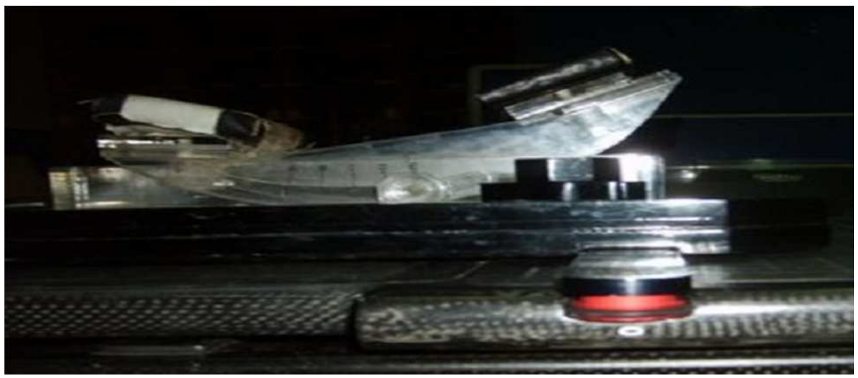
SET UP & POSITIONING

- Important component of conformal RT
- Position
  - Should be comfortable & Reproducible
  - Should be suitable for beam entry, with minimum accessories in beam path
- For this purpose positioning devices may be used
- *Positioning devices* are ancillary devices used to help maintain the patient in a non-standard treatment position.

TIMO

Belly board

PITUITARY BOARD



Face rest

Breast board

Knee wedge

IMMOBILIZATION

- Patient is immobilized using individualized casts or moulds.
- An *immobilization device* is any device that helps to establish and maintain the patient in a fixed, well-defined position from treatment to treatment over a course of radiotherapy-reproduce the treatment everyday

Image Acquition for Target and treatment verification

- It provides foundation for treatment planning
- Usually more than one imaging modalities are required for better delineation of target volume

- Images are acquired for :
  - Treatment planning
  - Image guidance and/or treatment verification
  - Follow-up studies (during & after treatment)

IMAGING MODALITIES

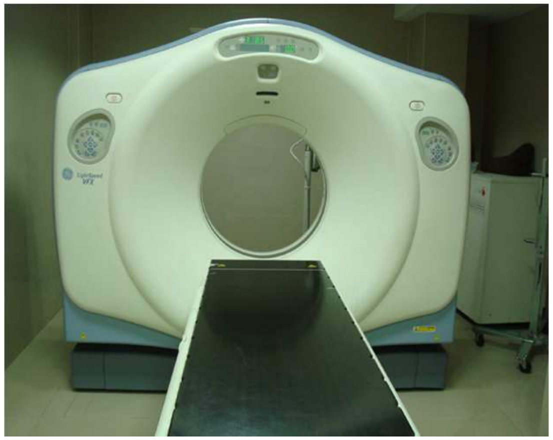
- No single imaging modality produces all the information, needed for the accurate identification and delineation of the target volume and critical organs.

- Various imaging modalities used are :
  - CT
  - MRI
  - PET-CT

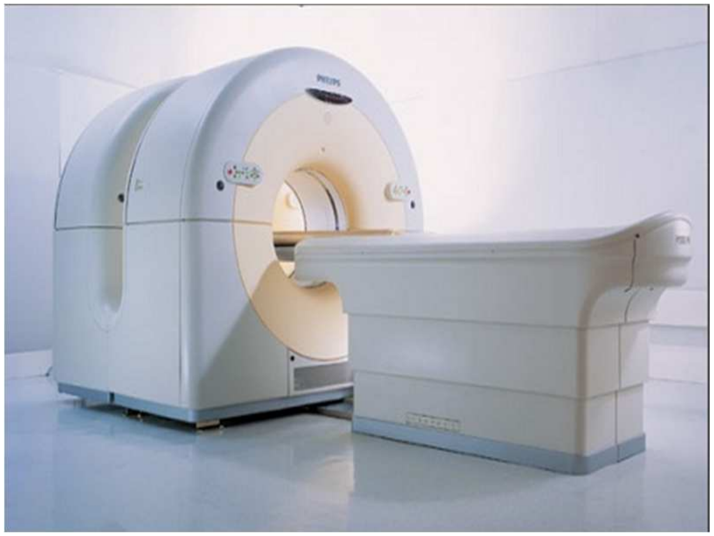
High Tech Diagnostic Machines

CT Simulator

MRI



PET Scan



CT IMAGING

- Advantages of CT
  - Gives quantitative data in form of CT no. (electron density) to account for tissue heterogeneities while computing dose distribution.
  - Gives detailed information of bony structures
  - Potential for rapid scanning
  - 4 -D imaging can be done.
  - Widely available; (relatively) inexpensive

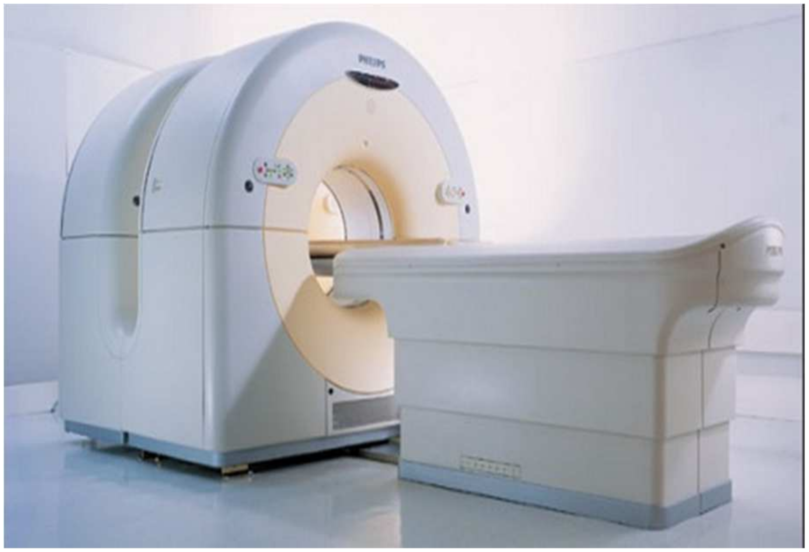
MRI IMAGING

- Advantages of MRI
  - No radiation dose to patient
  - Unparalleled soft tissue delineation
  - scans directly in axial, sagittal, coronal or oblique planes
  - Vascular imaging with contrast agents

PET/CT

- Recently introduced PET/CT machines, integrating PET & CT technologies , enables the collection of both anatomical & biological information simultaneously

- ADV. of PET/CT
  - Earlier diagnosis of tumor
  - Precise localization
  - Accurate staging
  - Precise treatment
  - Monitoring of response to treatment



CT SIMULATOR

- Images are acquired on a dedicated CT machine called CT simulator with following features
  - A large bore (75-85cm) to accommodate various treatment positions along with treatment accessories.
  - A flat couch insert to simulate treatment machine couch.
  - A laser system consisting of
    - Inner laser
    - External moving laser to position patients for imaging & for marking
    - A graphic work station

IMAGE ACQUISITION

- CT is done with pt in the treatment position with immobilization device if used.
- Radio opaque fiducial are placed .
- These fiducial assist in any coordinate transformation needed as a result of 3D planning and eventual plan implementation.
- A topogram is generated to insure that patient alignment is correct & then using localizer, area to be scanned is selected.
- The FOV is selected to permit visualization of the external contour, which is required for accurate dose calculations.
- Using site dependent protocols, images are acquired.
- The planning CT data set is transferred to a 3D-TPS or workstation via a computer network.

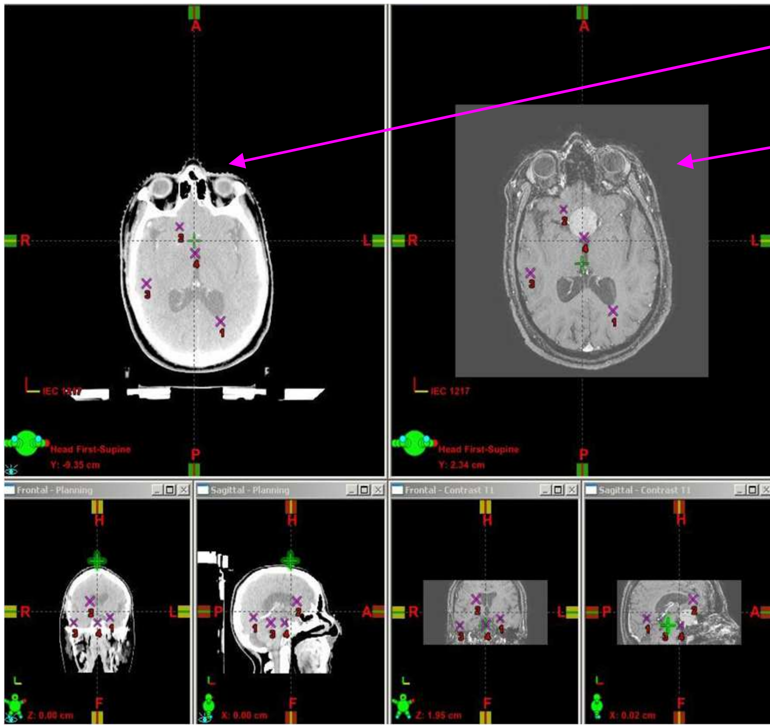
IMAGE REGISTRATION

- registration allows use of complementary features of different scan types.
- Employs a unique algorithm that allows full voxel to voxel intensity match, Image Fusion automatically correlates thousands of points from two image sets, providing true volumetric fusion of anatomical data sets.
- This requires calculation of 3D transformation that relates coordinates of a particular imaging study to planning CT coordinates.
- Various registration techniques include
  - Point-to-point fitting,
  - Line or curve matching
  - Surface or topography matching
  - Volume matching

CT IMAGE

MRI IMAGE

POINT TO POINT MATCHING



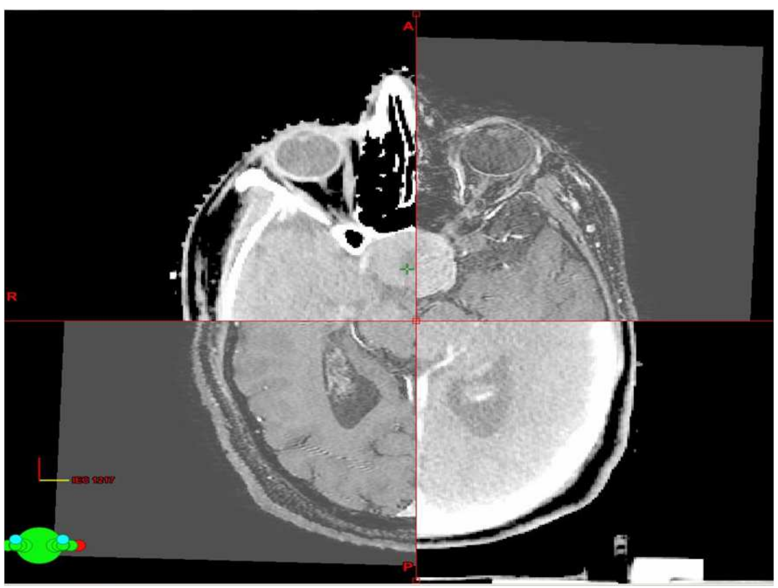
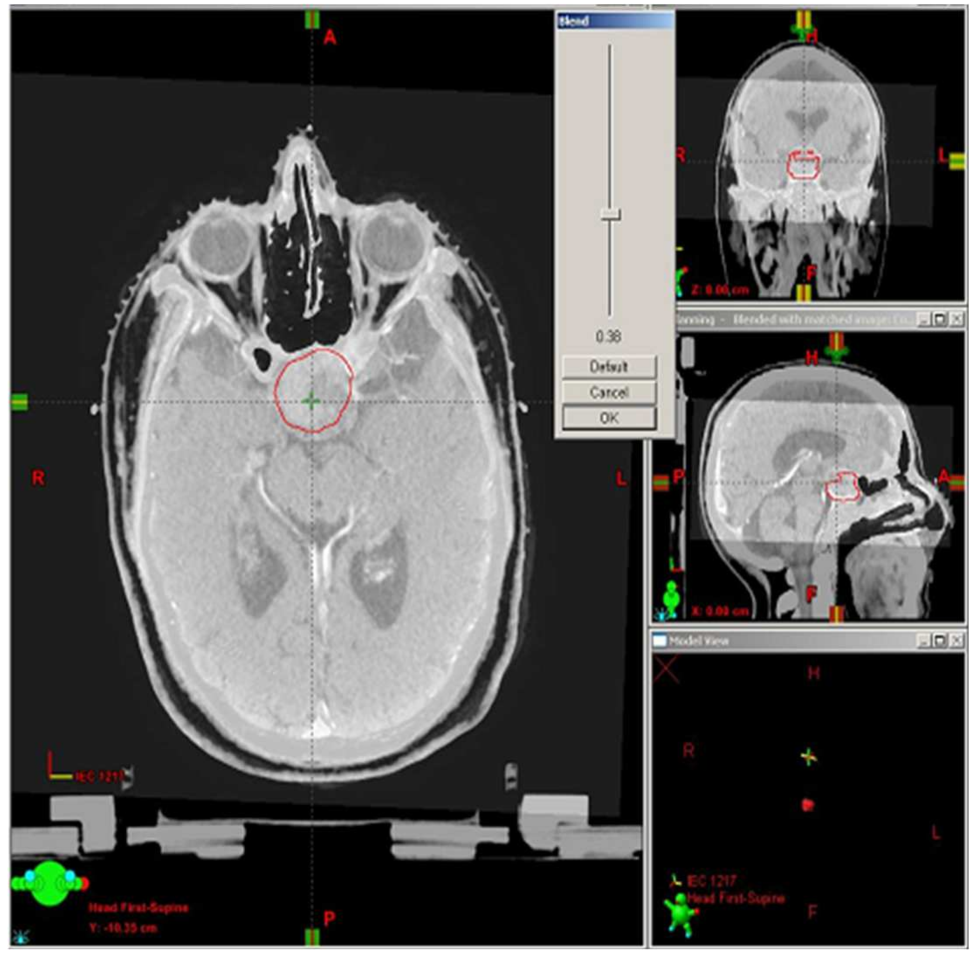


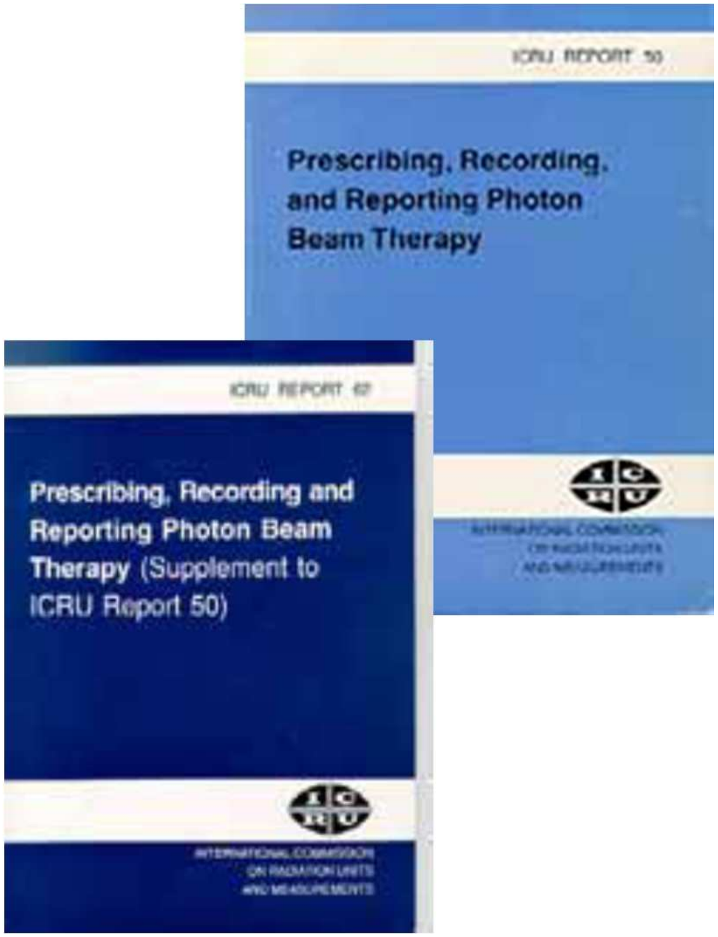
IMAGE FUSION



CONTOURING ON BLENDED IMAGE

VOLUME DEFINITION

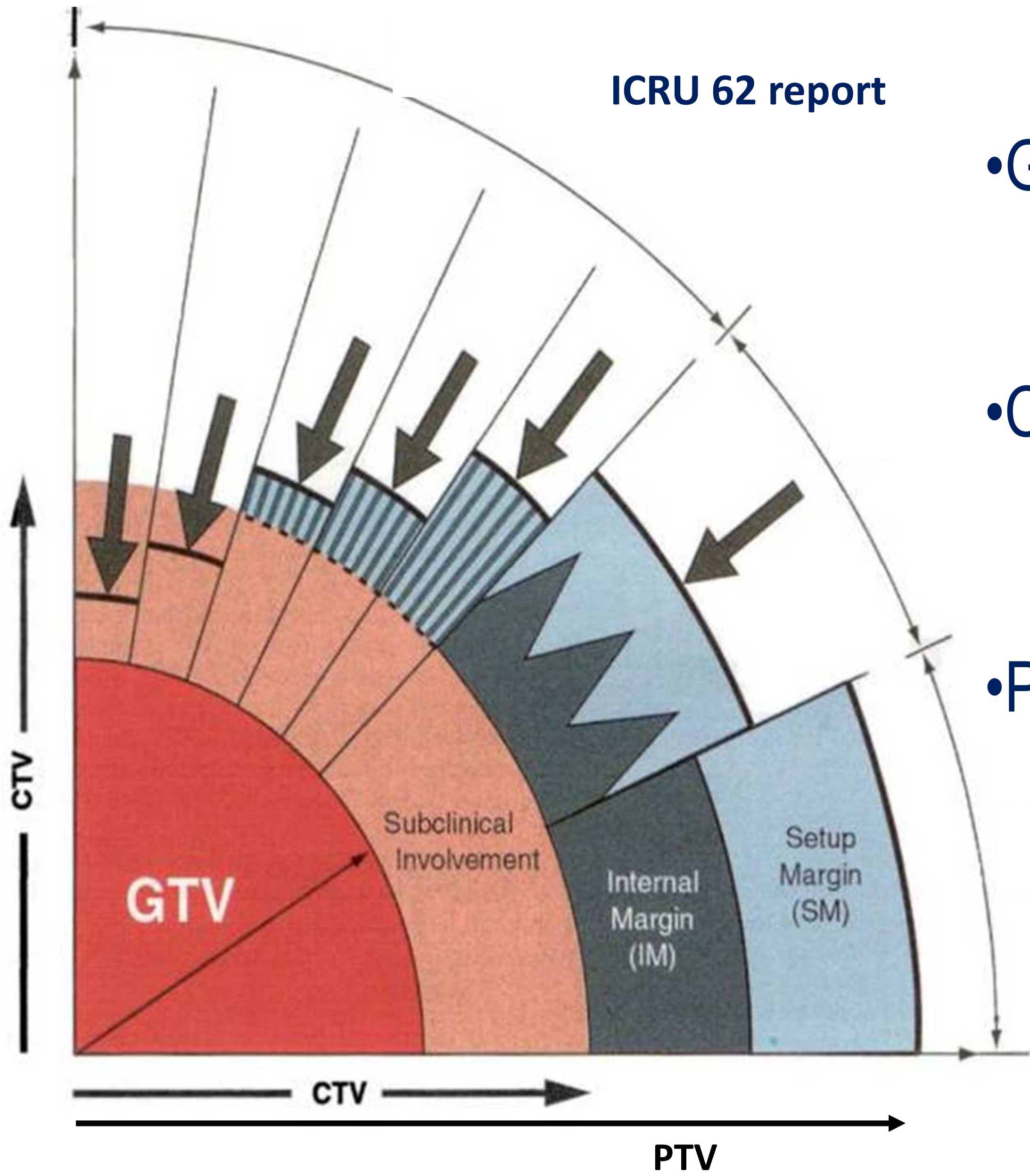
- Volume definition is prerequisite for 3-D treatment planning.
- To aid in the treatment planning process & provide a basis for comparison of treatment outcomes.
- ICRU reports50 & 62 define & describe target & critical structure volumes.



Defining Target Volumes and OAR

The new
ICRU Report 83

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

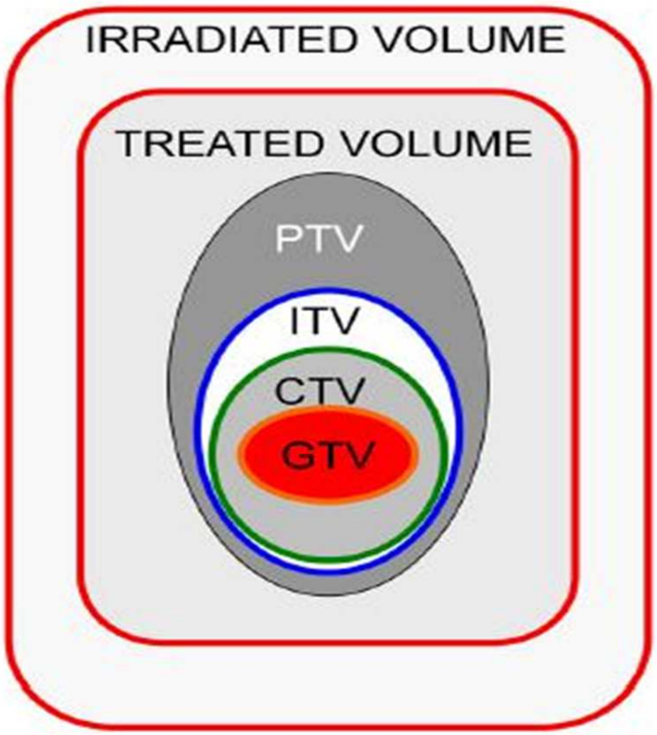
Baumert et al. IJROBP 2006 Sep 1;66(1):187-94

ICRU 83 (2010)

As introduced in ICRU Reports 50, 62, 71, and 78 (ICRU, 1993; 1999; 2004; 2007)

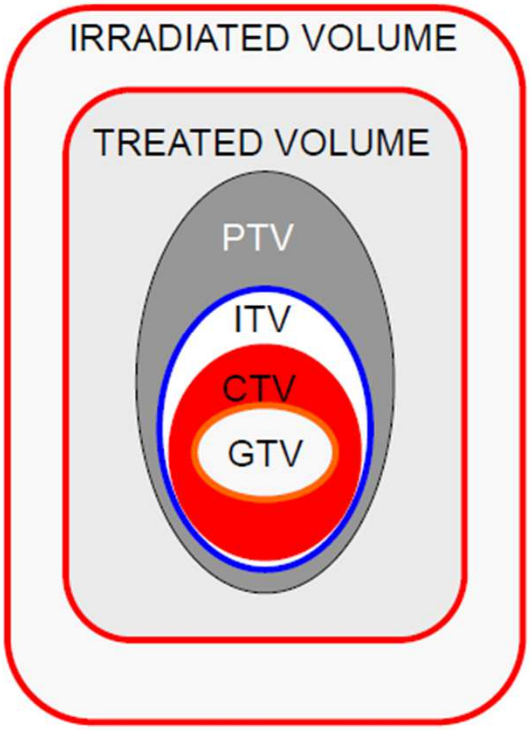
- Gross tumor volume or **GTV**
- Clinical target volume or **CTV**
- Planning target volume or **PTV**
- Organ at risk or **OAR**
- Planning organ-at-risk volume or **PRV**
- Internal target volume or **ITV**
- Treated volume or **TV**
- Remaining volume at risk or **RVR**

ICRU 50/62/83



- **Gross tumor volume (GTV): Tumor visible on (CT, MRI, PET, clinical etc.)**

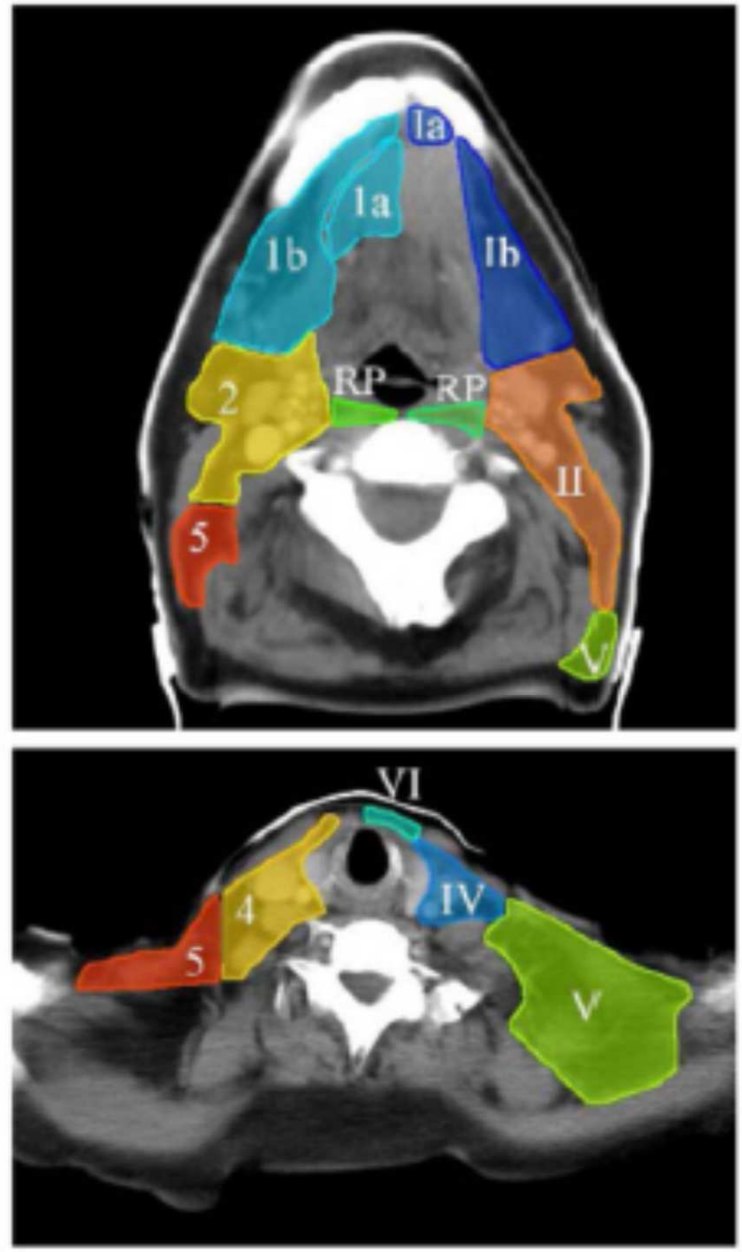
Clinical Target Volume



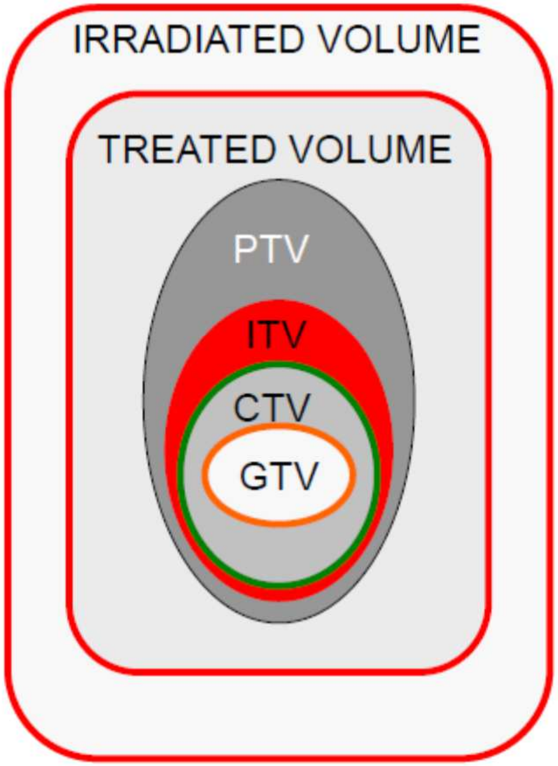
Is a tissue volume that contains a demonstrable GTV and/or <u>subclinical malignant disease</u> that must be eliminated.

This volume must be treated adequately in order to achieve the aim of radical therapy.

- CTV HR
- CTV IR
- CTV LR

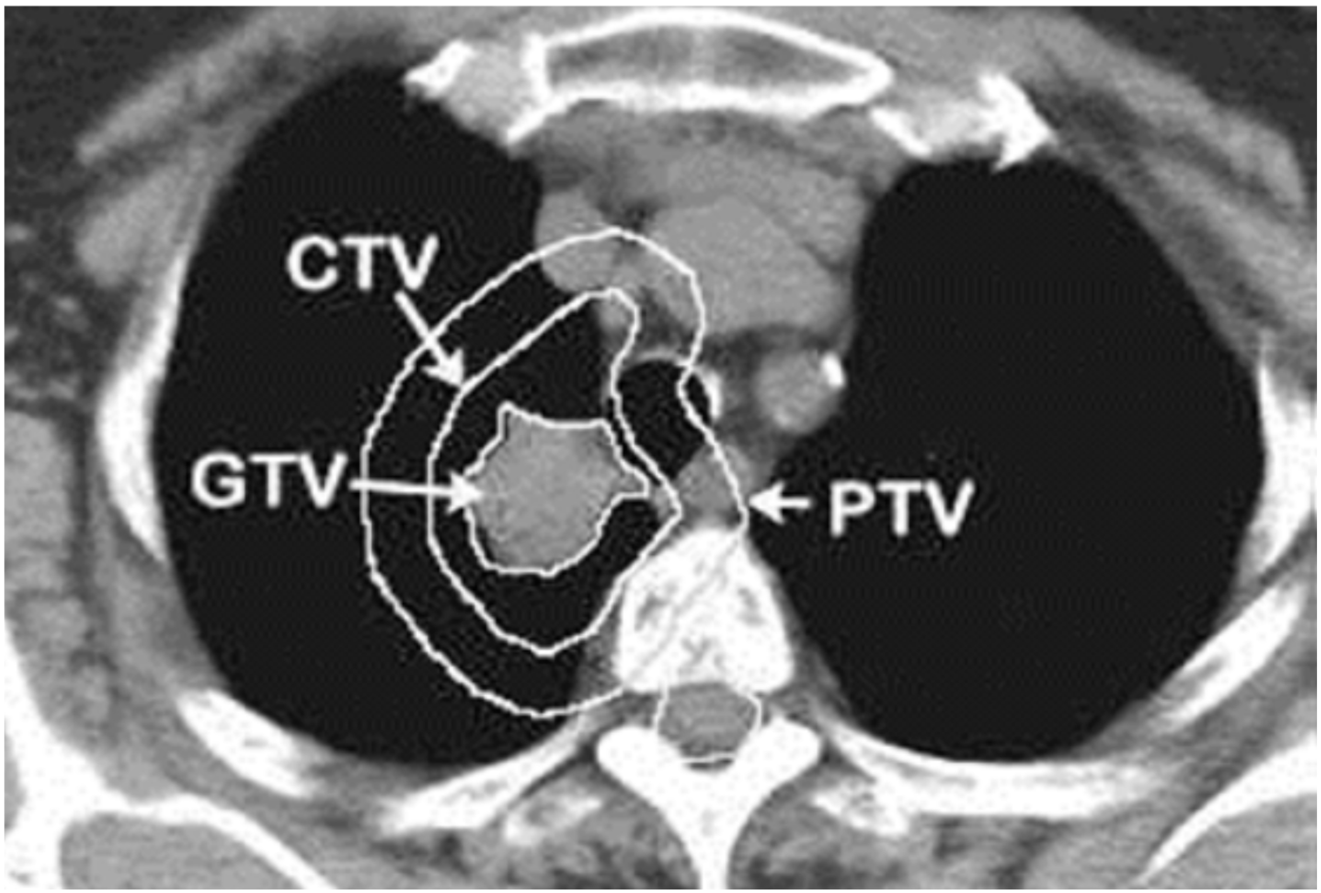


Internal Target Volume

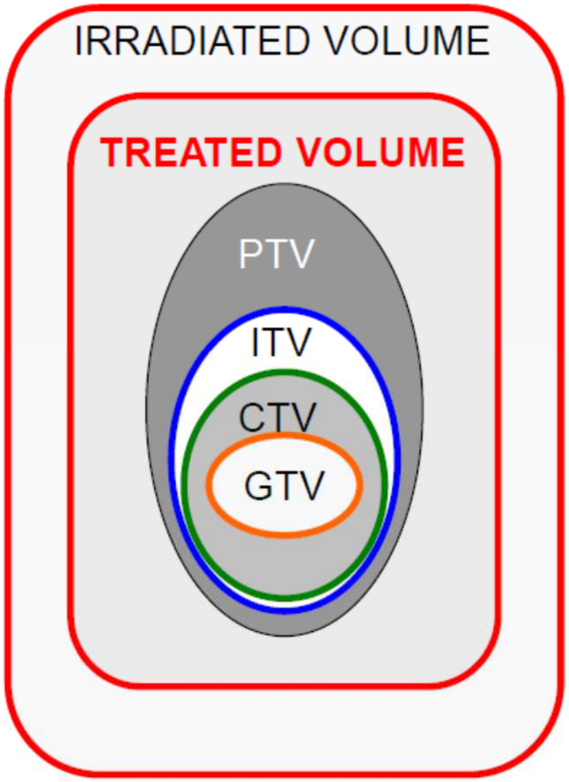


A margin must be added to the CTV <u>to compensate for expected physiologic movements and variations in size, shape and position of the CTV during therapy.</u>
Includes the CTV and an "Internal Margin"

PTV = CTV + patient movements, set-up and beam inaccuracies

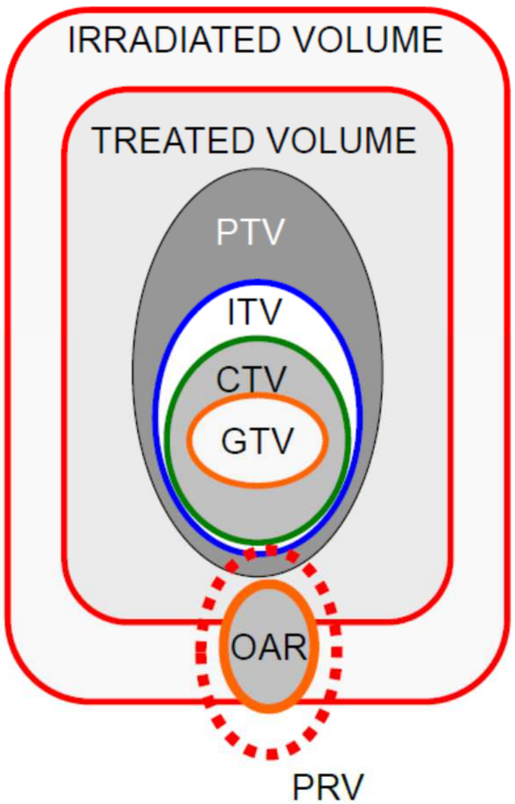


Treated Volume



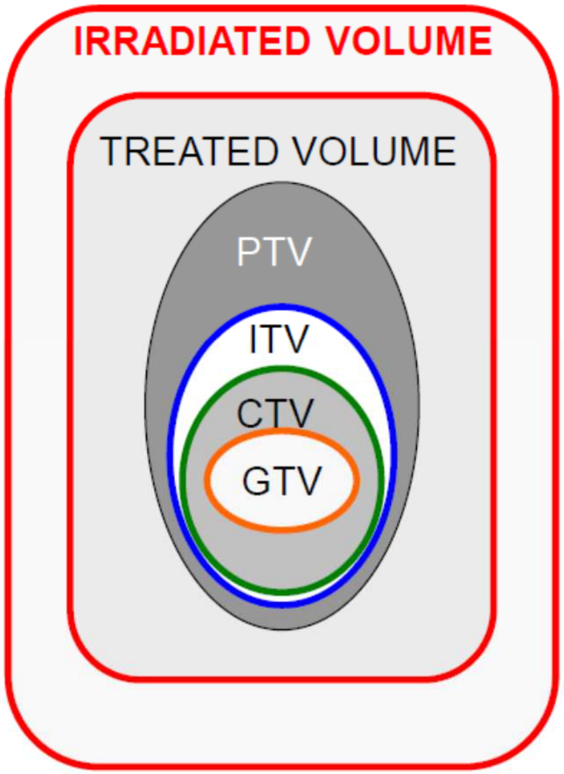
Is the tissue volume that (according to the approved treatment plan) is planned to receive at least a dose selected and specified by the radiation oncology team as being appropriate to achieve the purpose of treatment e.g. tumour eradicaton or palliation, within the bound of acceptable complications.

Organs At Risk



- **Organ at risk (OAR): Organ whose radiation sensitivity is such that the dose recei-ved by during treatment may be significant compared to its tolerance.**
- **OARs may significantly influence treatment planning and/or prescribed dose.**

Irradiated Volume



Is the tissue volume that receives a dose that is considered significant in relation to normal tissue tolerance.

Remaining Volume at Risk

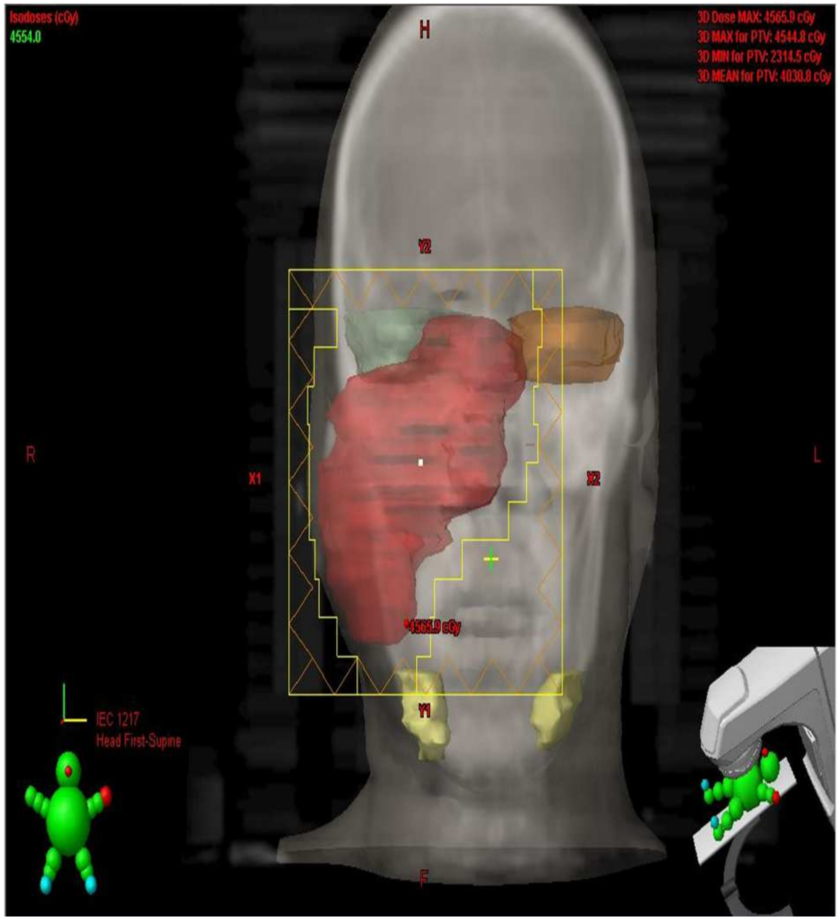
The RVR is defined by the difference between the volume enclosed by the external contour of the patient and that of the CTVs and OARs on the slices that have been imaged.

TREATMENT PLANNING SYSTEM

- TPS provides tools for
  - Image registration
  - Image segmentation or contouring
  - Virtual Simulation
  - Dose calculations
  - Plan Evaluation
  - Data Storage and transmission to console
  - Treatment verification

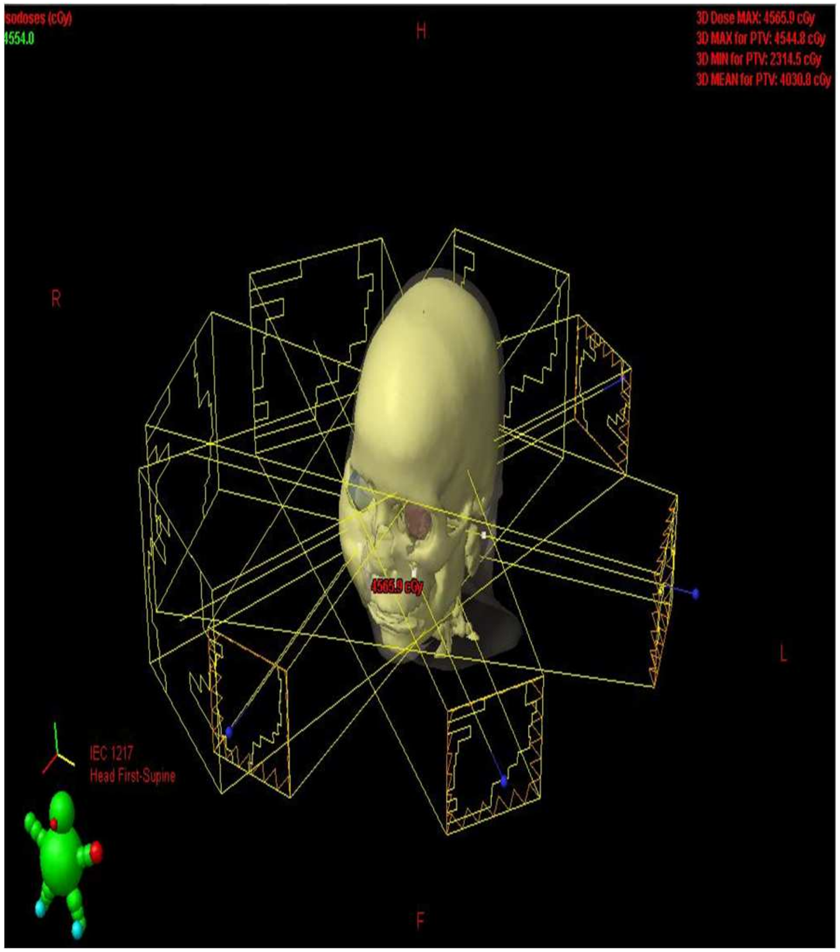
Virtual Simulation Beam Eye View-BEV

- In BEV observer's viewing point is at the source of radiation looking out along axis of radiation beam.
  - Demonstrates geometric coverage of target volume by the beam
  - Shielding & MLCs are designed on BEV
  - Useful in identifying best gantry, collimator, and couch angles to irradiate target & avoid adjacent normal structures by interactively moving patient and treatment beam.



Room Eye View-REV

- The REV display provides a viewing point simulating any arbitrary location within the treatment room.
-
- The REV helps
  - To better appreciate overall treatment technique geometry and placement of the isocenter



PLANNING

- For planning, the 3D TPS must have the capability to simulate each of the treatment machine motion functions, including
  - Gantry angle,
  - Collimator length, width & angle,
  - MLC leaf settings,
  - Couch latitude, longitude, height & angle.

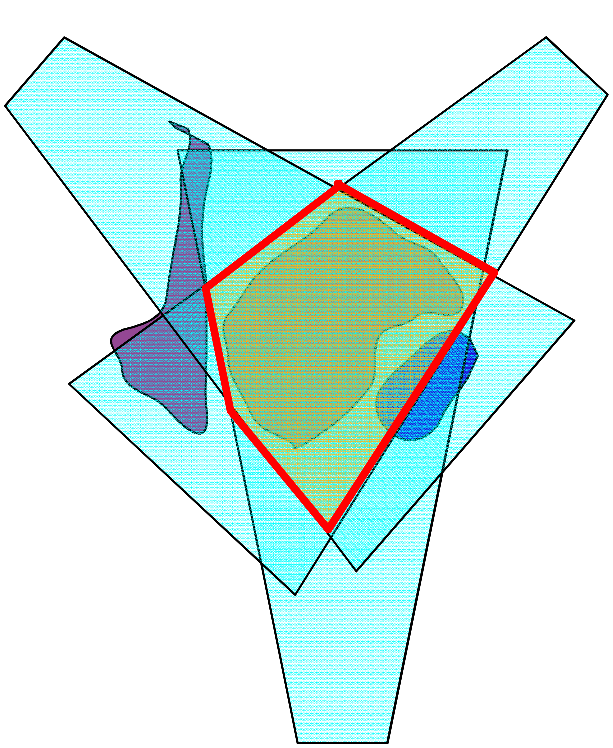
FORWARD PLANNING

- For 3D CRT forward planning is used.
- Beam arrangement is selected based on clinical experience.
- Using BEV, beam aperture is designed
- Dose is prescribed.
- 3D dose distribution is calculated.
- Then plan is evaluated.
- Plan is modified based on dose distribution evaluation, using various combinations of
  - Beam , collimator & couch angle,
  - Beam weights &
  - Beam modifying devices (wedges, compensators) to get desired dose distribution.

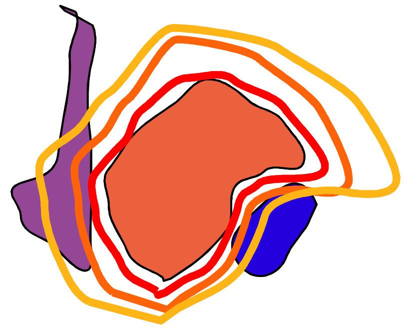
IMRT PLANNING

- IMRT planning is an **inverse planning.**
- It is so called because this approach starts with desired result (a uniform target dose) & works backward toward incident beam intensities.
- After contouring, treatment fields & their orientation (beam angle) around patient is selected.
- Next step is to select the parameters used to drive the optimization algorithm to a particular solution.
- Optimization refers to mathematical technique of
  - finding the best physical and technically possible treatment plan
  - to fulfill specified physical and clinical criteria,
  - under certain constraints
  - using sophisticated computer algorithm

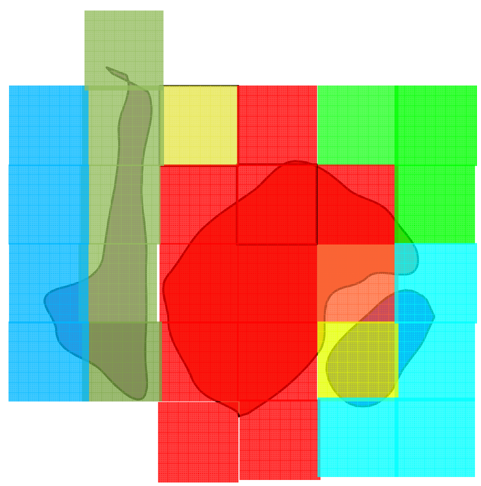
INVERSE PLANNING



Forward Planning

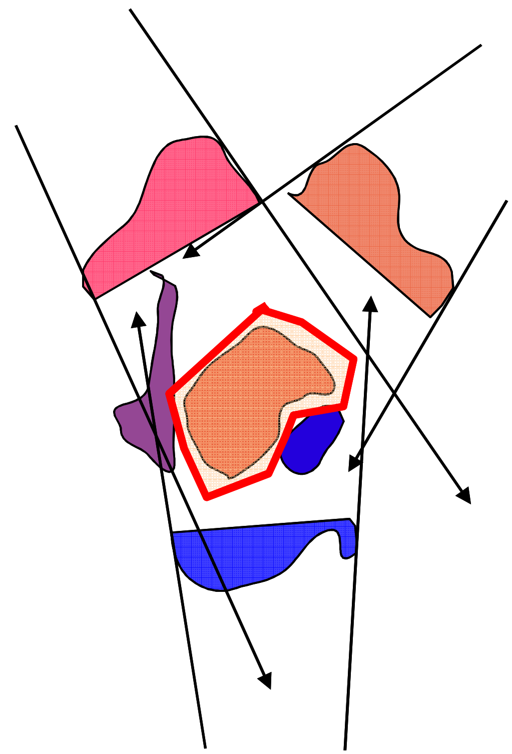


1. Dose distribution specified



2. Intensity map created

Inverse Planning



3. Beam Fluence modulated to recreate intensity map

- Dose-volume constraints for the target and normal tissues are entered into the optimization program of TPS
  - Maximum and minimum target doses
  - Maximum normal tissues doses
  - Priority scores for target and normal tissues
- The dose prescription for IMRT is more structured and complex than single-valued prescription used in 3-D CRT & conventional RT
- Ideally some dose value is prescribed to every voxel.

OPTIMIZATION

- Refers to the technique of finding the **best** physical and technically possible treatment plan to fulfill the **specified** physical and clinical criteria.

- A mathematical **technique** that aims to maximize (or minimize) a **score** under certain **constraints**.

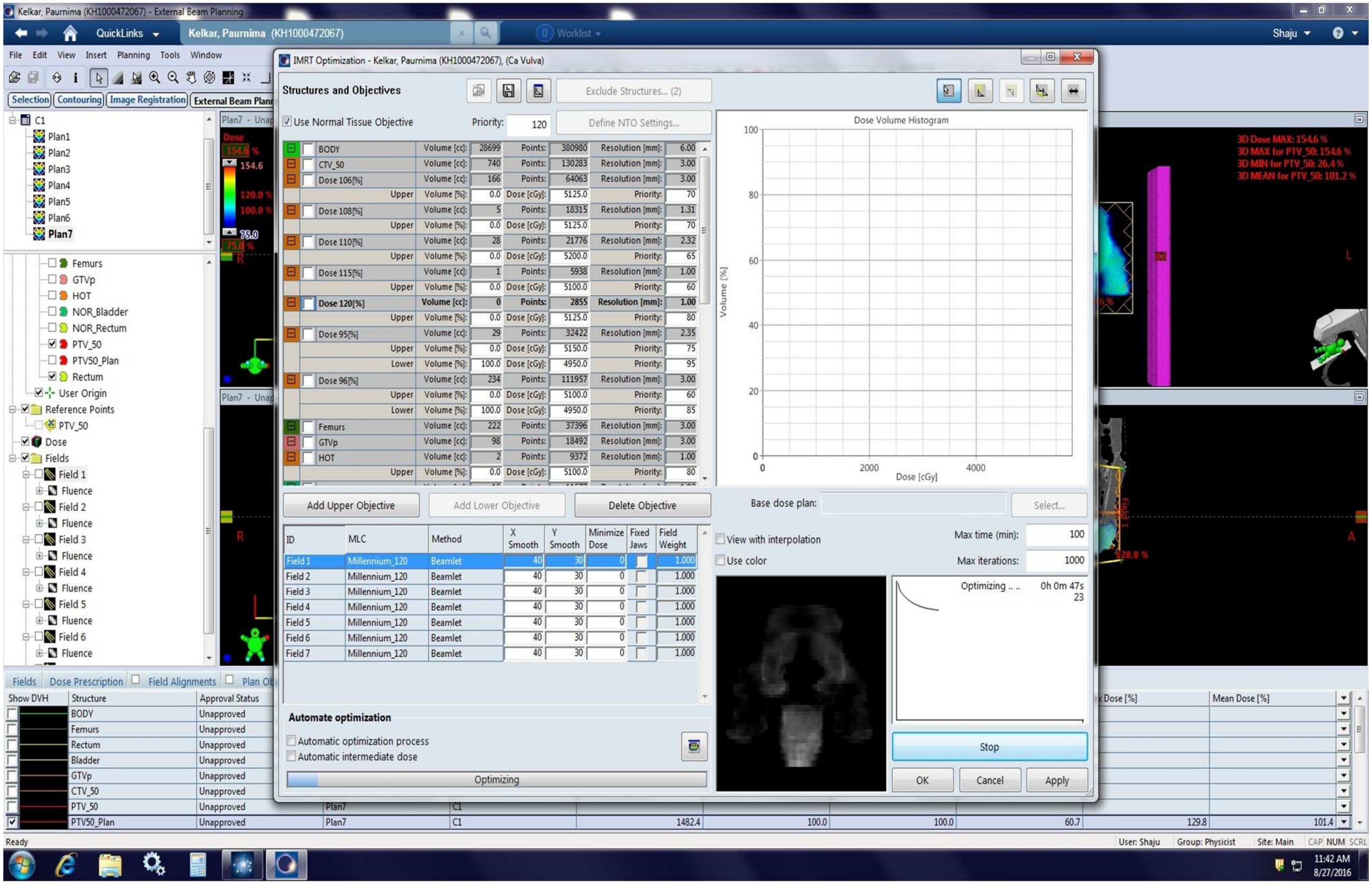
- It is one of the most commonly used techniques for inverse planning.

- During the optimization process, each beam is divided into small “beamlets”
- Intensity of each is varied until the optimal dose distribution is derived

- We can Optimize following parameters
  - **Intensity maps**
  - **Number of intensity levels**
  - Beam angles
  - Number of beams
  - Beam Energy

- **Types**:
  - Physical Optimization Criteria: Based on physical dose coverage
  - Biological Optimization Criteria: Based on TCP and NTCP calculation
- A total objective function (**score**) is then derived from these criteria.
- Priorities are defined to tell the algorithm the relative importance of the different planning objectives (**penalties**)
- The algorithm attempts to **maximize** the score based on the criteria and penalties.

Planning Window

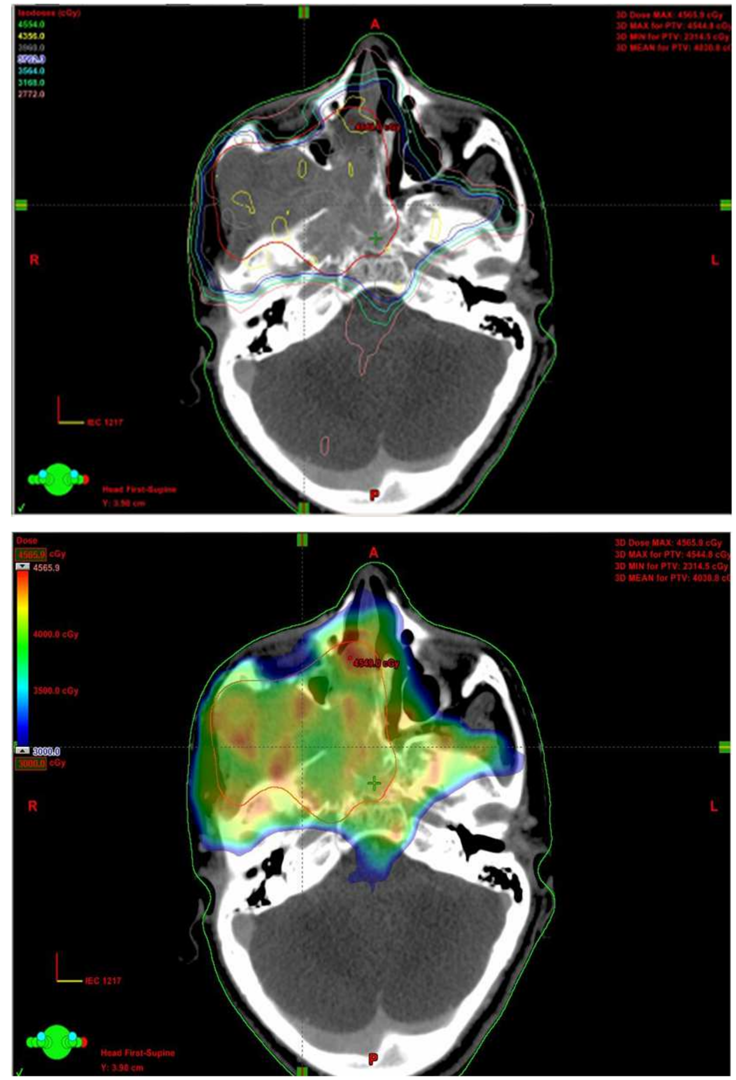


PLAN EVALUATION

- The following tools are used in the evaluation of the planned dose distribution:
  - 2-D display
    - Isodose lines
    - Color wash
    - DVHs (Dose volume histograms)
  - Dose distribution statistics

2D EVALUATION

- Isodose lines superimposed on CT images
- Color wash - Spectrum of colors superimposed on the anatomic information represented by modulation of intensity
  - Gives quick over view of dose distribution
  - Easy to assess overdosage in normal tissue that are not contoured.
  - To assess dose heterogeneity inside PTV
- Slice by slice evaluation of dose distribution can be done.

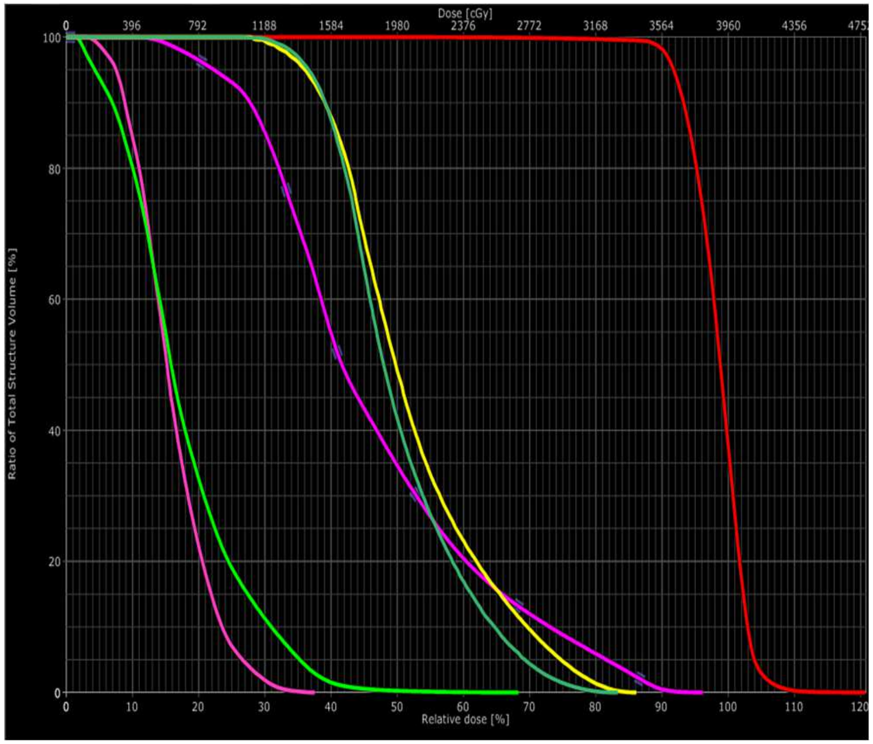


DOSE VOLUME HISTOGRAM - DVH

- DVHs summarize the information contained in the 3-D dose distribution & quantitatively evaluates treatment plans.
- DVHs are usually displayed in the form of ‘per cent volume of total volume’ against dose.
- The DVH may be represented in two forms:
  - Cumulative integral DVH
  - Differential DVH.

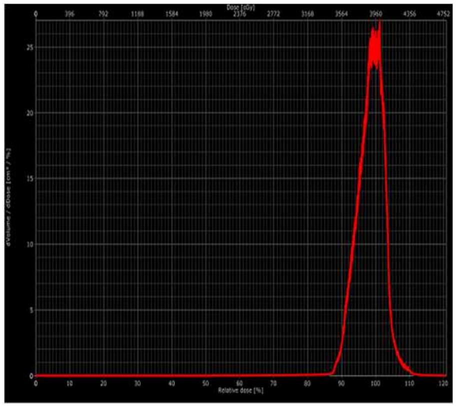
CUMULATIVE DVH

- It is plot of volume of a given structure receiving a certain dose.
- Any point on the cumulative DVH curve shows the volume of a given structure that receives the indicated dose or **higher**.
- It start at 100% of the volume for zero dose, since all of the volume receives at least more than zero Gy.

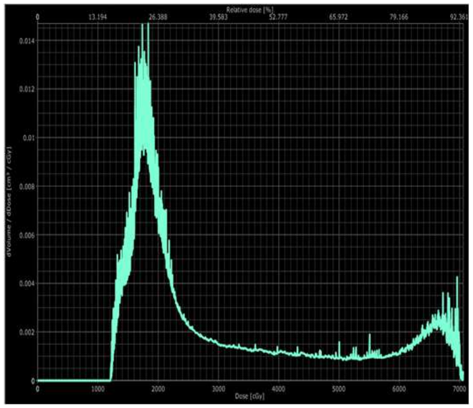


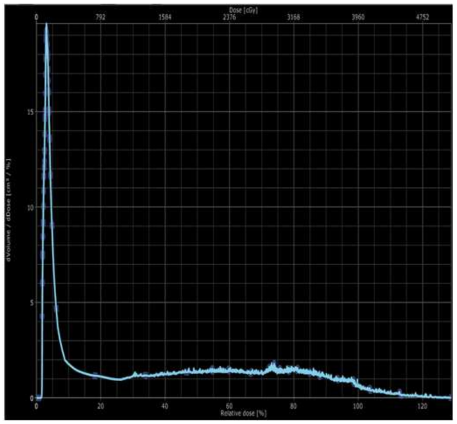
DIFFERENTIAL DVH

- The direct or differential DVH is a plot of volume receiving a dose within a specified dose interval (or dose bin) as a function of dose.
- It shows extent of dose variation within a given structure.
- The ideal DVH for a target volume would be a single column indicating that 100% of volume receives prescribed dose.
- For a critical structure, the DVH may contain several peaks indicating that different parts of the organ receive different doses.



DVH - target vol.

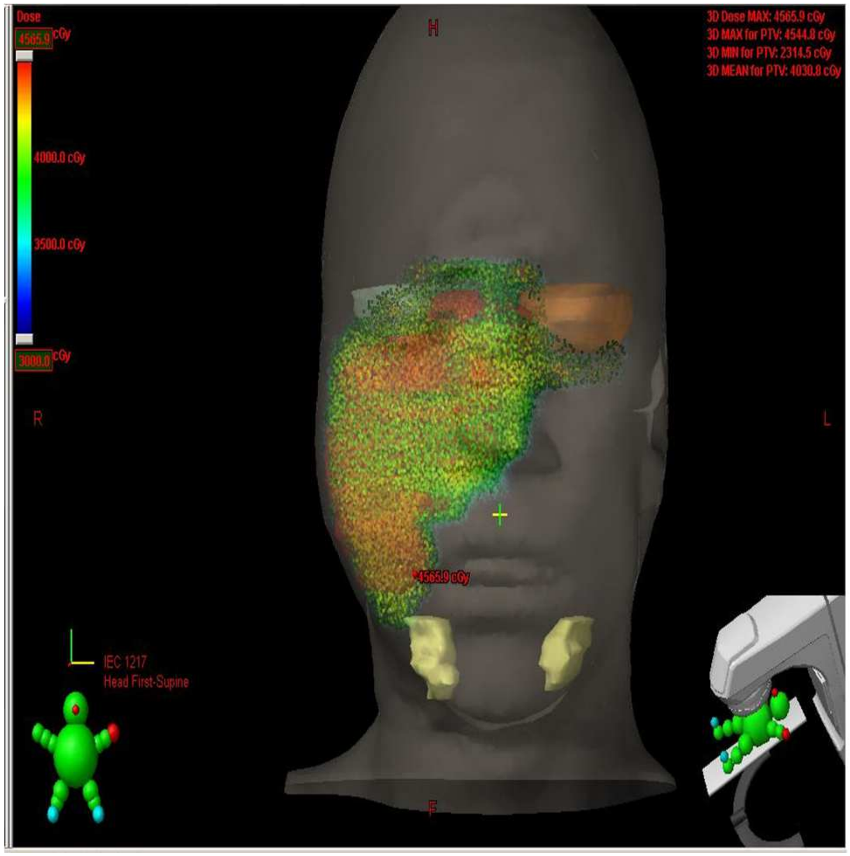




DVH - OAR

3-D DOSE CLOUD

- Map isodoses in three dimensions and overlay the resulting isosurface on a 3-D display with surface renderings of target & other contoured organs.



Dose statistics

- It provide quantitative information on the volume of the target or critical structure and on the dose received by that volume.
- These include:
  - The minimum dose to the volume
  - The maximum dose to the volume
  - The mean dose to the volume
  - Modal dose
- Useful in dose reporting.

Fields | Dose Prescription | Field Alignments | Plan Objectives | Optimization Objectives | Dose Statistics | Calculation Models | Plan Sum

Show DVH	Structure	Approval Status	Plan	Course	Volume [cm^3]	Dose Cover.[%]	Sampling Cover.[%]	Min Dose [cGy]	Max Dose [cGy]	Mean Dose [cGy]
☑	BODY	Approved	F	C1	20332.5	100.0	100.0	0.0	5228.6	486.9
☑	Bowel	Approved	F	C1	1132.9	100.0	100.0	56.5	5194.6	1891.7
☑	CTV_45	Approved	F	C1	222.2	100.0	100.0	4537.5	5228.6	4972.7
☑	CTV_5.4	Approved	F	C1	95.7	100.0	100.1	4858.5	5228.6	5064.7
☑	CTV_pancreas	Approved	F	C1	108.3	100.0	100.0	4089.9	5228.6	5062.0
☑	D 96[%]	Approved	F	C1	12.5	100.0	98.2	2992.8	5211.0	4890.8
☑	Do 101[%]	Approved	F	C1	55.2	100.0	99.9	4861.9	5228.6	5080.2
☑	Dose 101[%]	Approved	F	C1	118.9	100.0	100.0	4535.3	5228.6	4977.4
☑	Dose 96[%]	Approved	F	C1	31.3	100.0	99.3	3929.3	5165.0	4691.1
☑	Duodenum	Approved	F	C1	66.9	100.0	100.0	742.8	5209.8	3847.1
☑	GTVp	Approved	F	C1	53.0	100.0	99.9	4860.0	5221.4	5070.5
☑	Kidney_L	Approved	F	C1	80.2	100.0	100.0	333.8	3566.0	1344.5
☑	Kidney_R	Approved	F	C1	79.7	100.0	100.0	351.4	5006.0	1467.6
☑	Liver	Approved	F	C1	817.5	100.0	100.0	80.8	5089.3	1495.2
☑	Nor_Bowel	Approved	F	C1	1096.7	100.0	100.0	56.5	5156.1	1794.1
☑	Nor_Duodenum1	Approved	F	C1	41.3	100.0	100.0	742.8	5048.2	3183.4
☑	Nor_Liver	Approved	F	C1	794.2	100.0	100.0	80.8	5016.3	1398.7
☑	Nor_Stomach1	Approved	F	C1	74.6	100.0	100.0	161.4	4986.9	2103.4
☑	PTV5.4	Approved	F	C1	177.2	100.0	100.0	4421.6	5228.6	5042.9
☑	PTV_45	Approved	F	C1	381.1	100.0	100.0	4142.8	5228.6	4916.4
☑	SpinalCord	Approved	F	C1	27.6	100.0	100.0	46.1	3282.0	1803.2
☑	Spleen	Approved	F	C1	48.6	100.0	100.0	159.2	3298.7	1439.7
☑	Stomach	Approved	F	C1	80.7	100.0	100.0	161.4	5083.1	2306.8

PLAN EVALUATION

- The planned dose distribution approved by the radiation oncologist is one in which
  - a uniform dose is delivered to the target volume (e.g., +7% and –5% of prescribed dose)
  - with doses to critical structures held below some tolerance level specified by the radiation oncologist
- Acceptable dose distribution is one that differs from desired dose distribution
  - within preset limits of dose and
  - only in regions where desired dose distribution can’t be physically achieved.

PLAN IMPLEMENTATION

- Once the treatment plan has been evaluated & approved, documentation for plan implementation must be generated.
- It includes
  - beam parameter settings transferred to the treatment machine's record and verify system,
  - MLC parameters communicated to computer system that controls MLC system of the treatment machine,
  - DRR generation & printing or transfer to an image database.

IMRT PLAN VERIFICATION

- The goal is to verify that correct dose & dose distribution will be delivered to the patient.
- One needs to check that
  - the plan has been properly computed
  - leaf sequence files & treatment parameters charted and/or stored in the R/V server are correct &
  - plan will be executable.
- Before first treatment, verification is done to check
  - MU (or absolute dose to a point)
  - MLC leaf sequences or fluence maps
  - Dose distribution

IMRT-QUALITY ASSURANCE

1/ Verify Leaf Positions

2/ Record and Verify System

3/ show leaf positions for each segment

4/ Portal Imaging

5/ Output tolerance tighter

6/ isocentre, mechanical tolerance tighter (smaller target)

7/Immobilization

8/Dose accuracy

IMAGE GUIDED RADIOTHERAPY

-

Need for Adaptive Radiotherapy

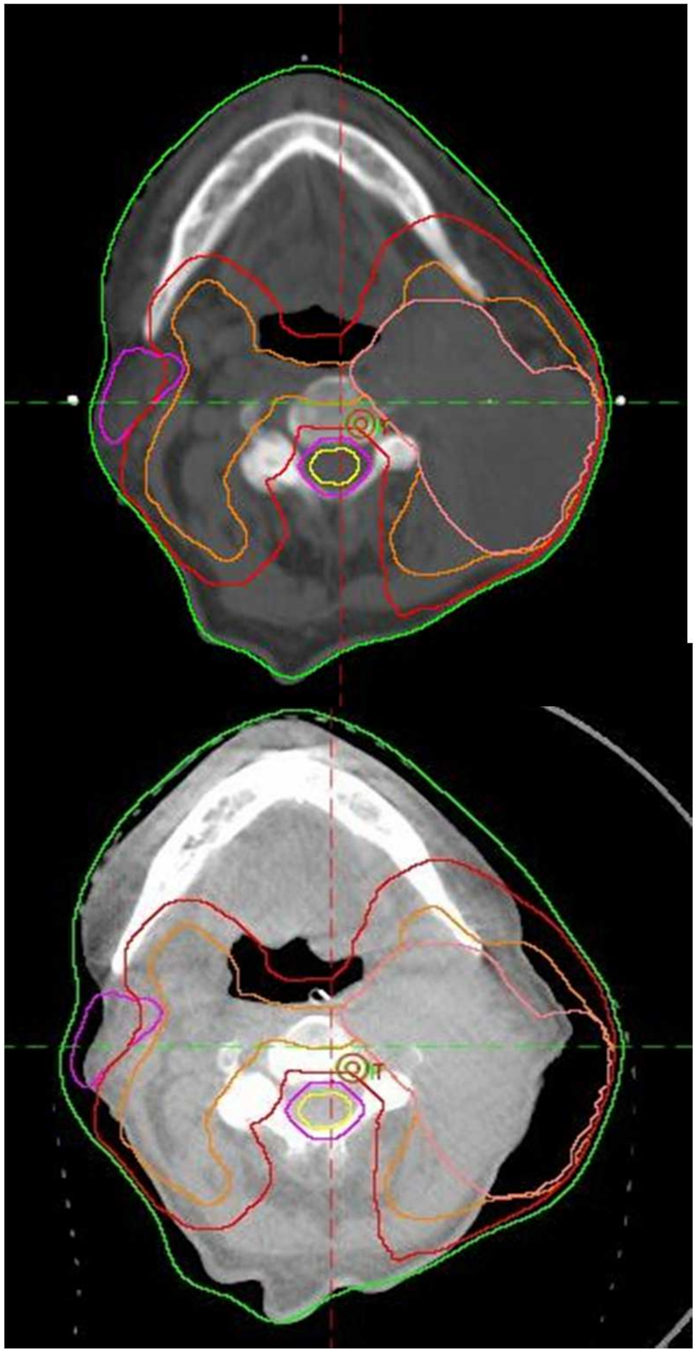
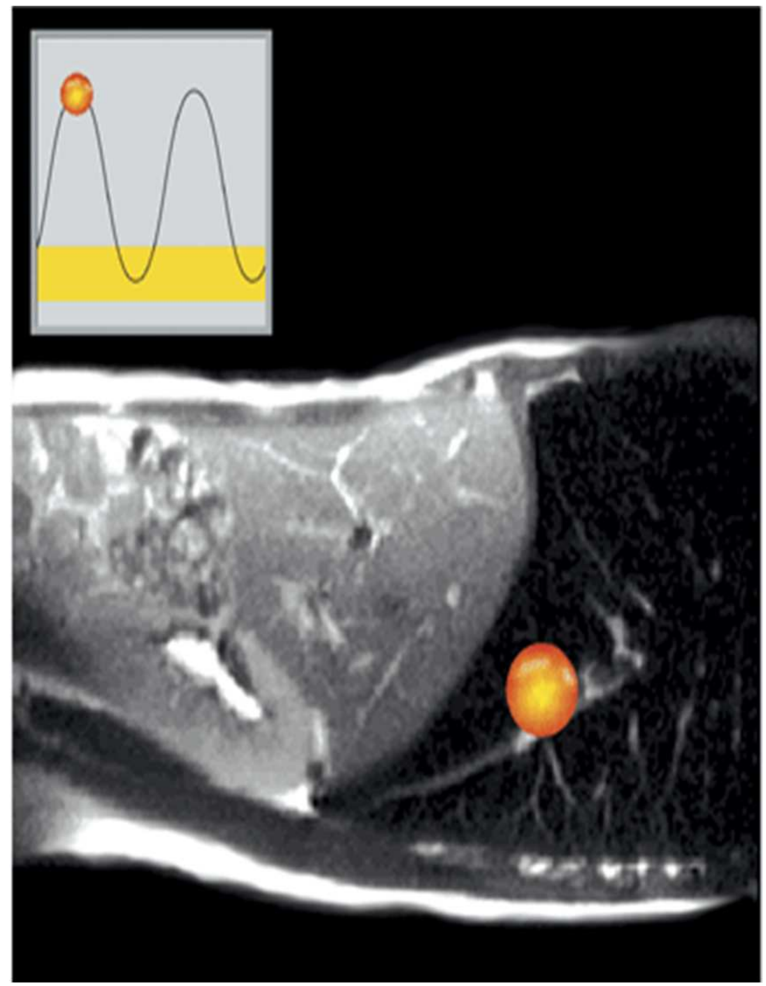


Image guidance will be an extremely important vision aid in delivering customised treatment according to each patient's need



Factors that contribute to positional or geometric uncertainty in target and nontarget organs

- Errors in target delineation and localization
- Interfraction patient setup errors and organ motion
- Intrafraction motion such as patient movement
- Respiratory and cardiac motion, and peristalsis

Stereotaxy

- Stereotactic radiosurgery (SRS) and stereotactic body radiotherapy (SBRT) have an established but evolving role in the management of malignant and benign conditions
- They have altered the way clinicians think about fractionation, and therefore they rank among the most important advances in radiation oncology

- **Ideal image-guided radiotherapy (IGRT) system should have three essential elements:**
  - **Three-dimensional (3-D) and, if possible, motion (four dimensional (4-D)) assessment of the target volume**
  - **Efficient comparison of the image data with reference data**
  - **Efficacious and fast process for clinically meaningful intervention (preferably fully automated).**

ASTRO Definition

- Stereotactic body radiation therapy (SBRT) is an external beam radiation therapy method that very precisely delivers a high dose of radiation to an extracranial target. SBRT is typically a complete course of therapy delivered in 1 to 5 sessions (fractions)

- A high degree of dose conformity is a hallmark of SRS
- Accuracy of beam delivery is crucial
- Involves:

  Imaging, target localization, immobilization and treatment setup

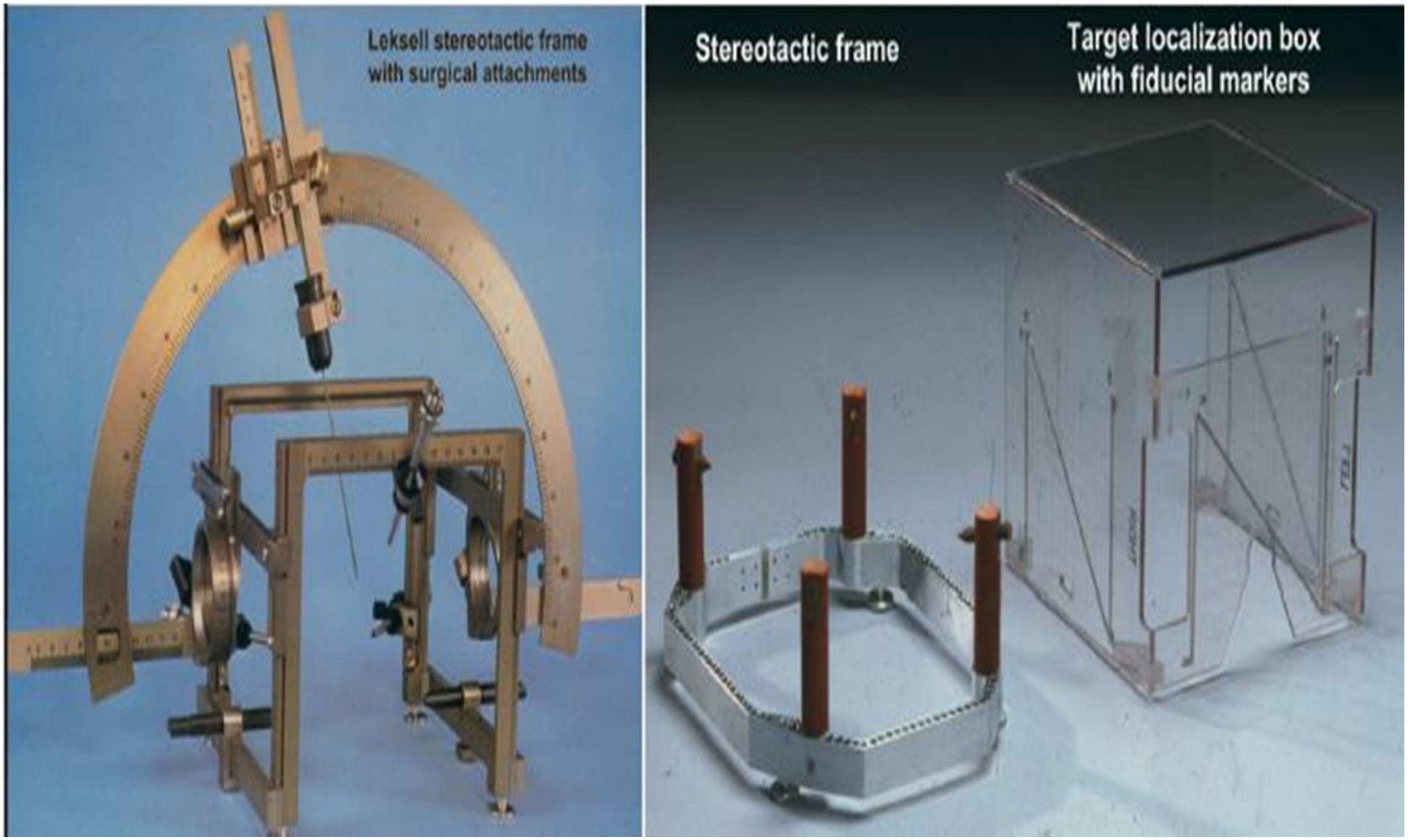
	Radiosurgery	Radiotherapy
Average Dose Per Fraction	High dose (~ 6 to 25 Gy per fraction)	Low dose (~ 2 Gy per fraction)
Typical # of Fractions	1 – 5 fractions	30 – 45 fractions
Typical # of Unique Beams Per Fraction	150 – 200	5 – 10
Typical Targeting Accuracy	< 1 millimeter	3 – 20 millimeters
Clinical Intent	Tumor ablation	Cumulative dose tumor control

Historical Landmarks in Radiosurgery 1951- 1980

Refining radiation sources, and techniques for radiosurgery

Year	Author	Location	Event
1951	Leksell	Stockholm (Karolinksa)	Invention of "Stereotactic Radiosurgery" using rotating orthovoltage unit
1954	Lawrence	Berkeley (Lawrence/Donner Labs)	Use of heavy particle treatment for pituitary for cancer pain
1962	Kjellberg	Boston (Harvard Cyclotron)	Use of proton beam for intracranial radiosurgery
1967	Leksell	Stockholm	Invention of Gammaknife using cobalt-60 sources
1970	Steiner	Stockholm	Use of Gammknife for AVM's
1980	Fabrikant	Berkeley (Donner Labs)	Use of Helium ions for AVM's

Frames , Frames and more Frames



Stereotactic Body Fix

Historical Landmarks in Radiosurgery
1994 -2009

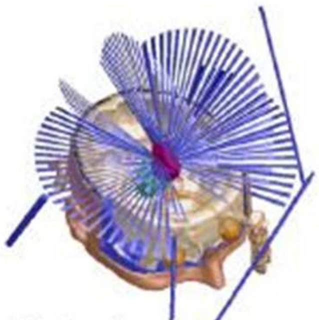
Towards improved conformality, image-guidance, frameless radiosurgery, and SBRT

Year	Author	Location	Event
1994	Lax Blomgren	Karolinska	Stereotactic treatments of abdominal tumors (1994)
1994	Adler	Stanford	First clinical use of prototype of Cyberknife
1995	Hamilton Lulu	Arizona	First report of SBRT case in North America
2000	Murphy	Stanford	Introduces image-guided radiotherapy
2003	Le/Whyte Timmerman	Stanford Indiana	Lung tumor SBRT
2004	Fuss Salter	San Antonio	SBRT with tomotherapy

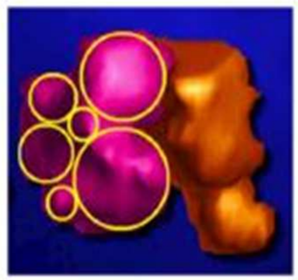
SRS and SBRT Systems

- Linac System
- Cyberknife
- Vero systems

Types of Photon Radiosurgery Planning



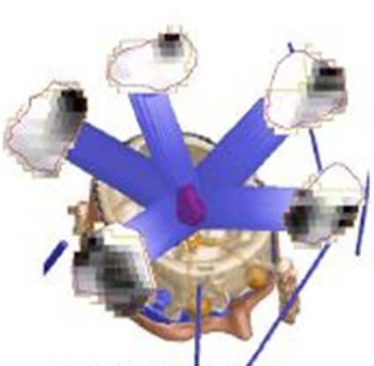
Circular Arc



Sphere Packing

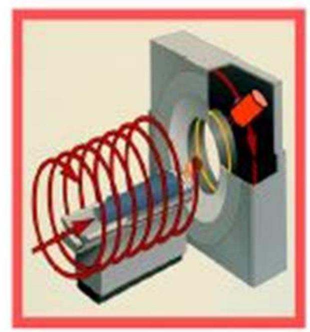
Conformal Shaped Beams

Dynamic Shaped Arcs



Intensity Modulated SRS/SRT

Volumetric Intensity Modulated Arcs



Tomotherapy

Non-isocentric dose painting

Quality Assurance

- Treatment QA and routine QA
- Treatment QA:

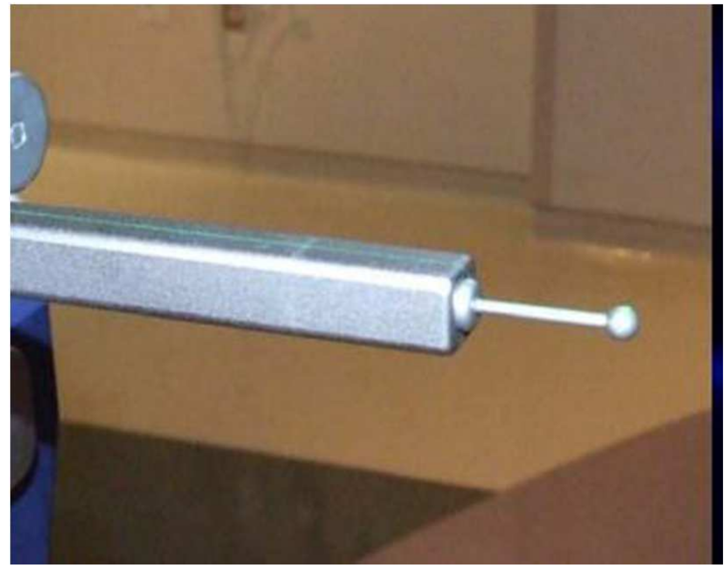
  Frame accuracy, imaging data transfer, frame alignment with gantry and couch, congruence of target point with radiation isocenter
- Routine QA:

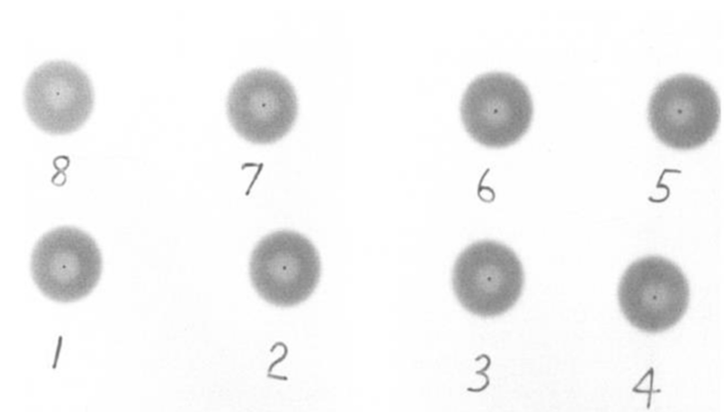
  Hardware/ Software

  Linac based: AAPM report 142 and 54

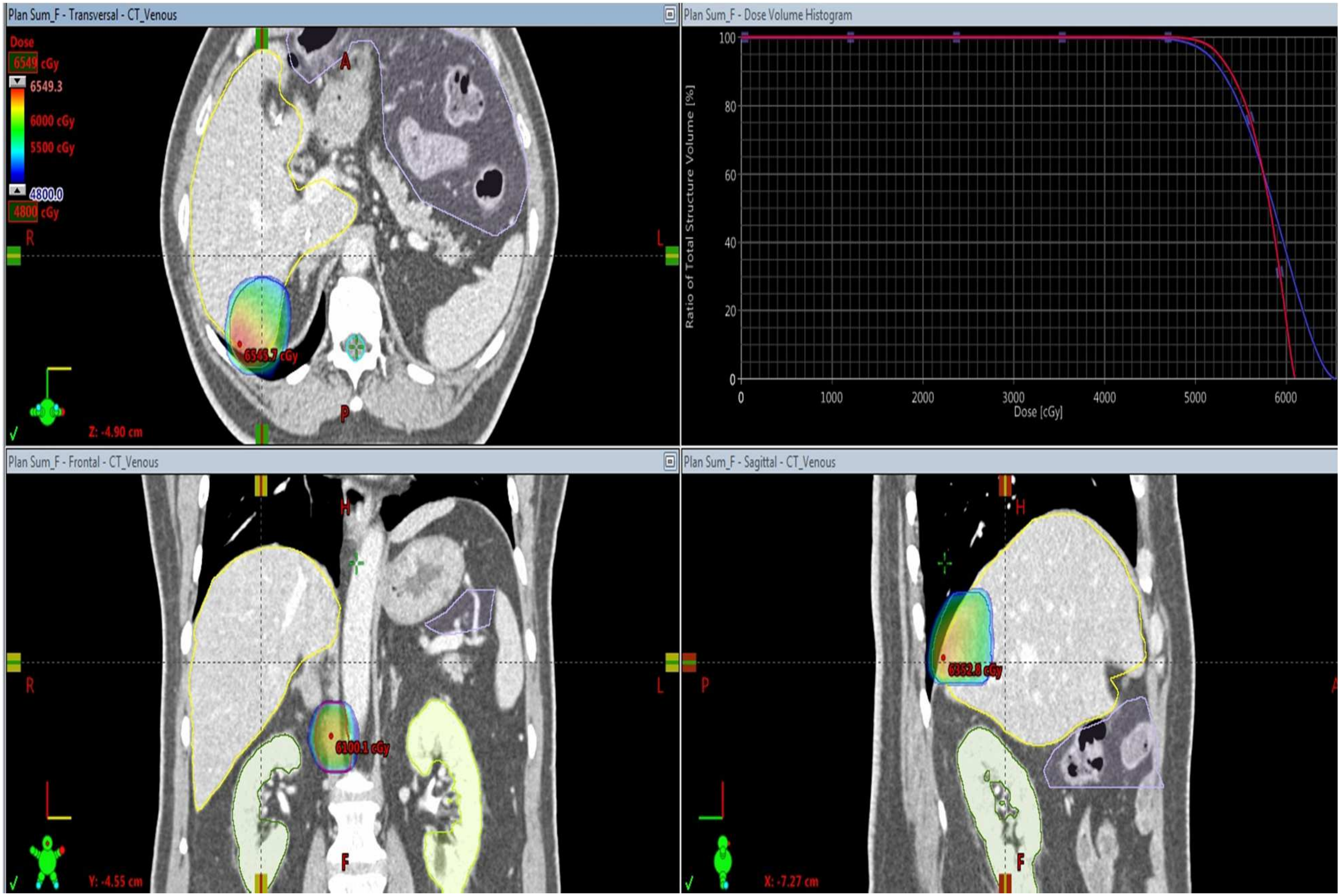
QA: Winston Lutz

Target simulator and the floor stand are independently set to the patient's target coordinates. If everything is aligned and set correctly, the ball bearing will remain in the center of the radiation beam regardless of the angle of the gantry /turntables

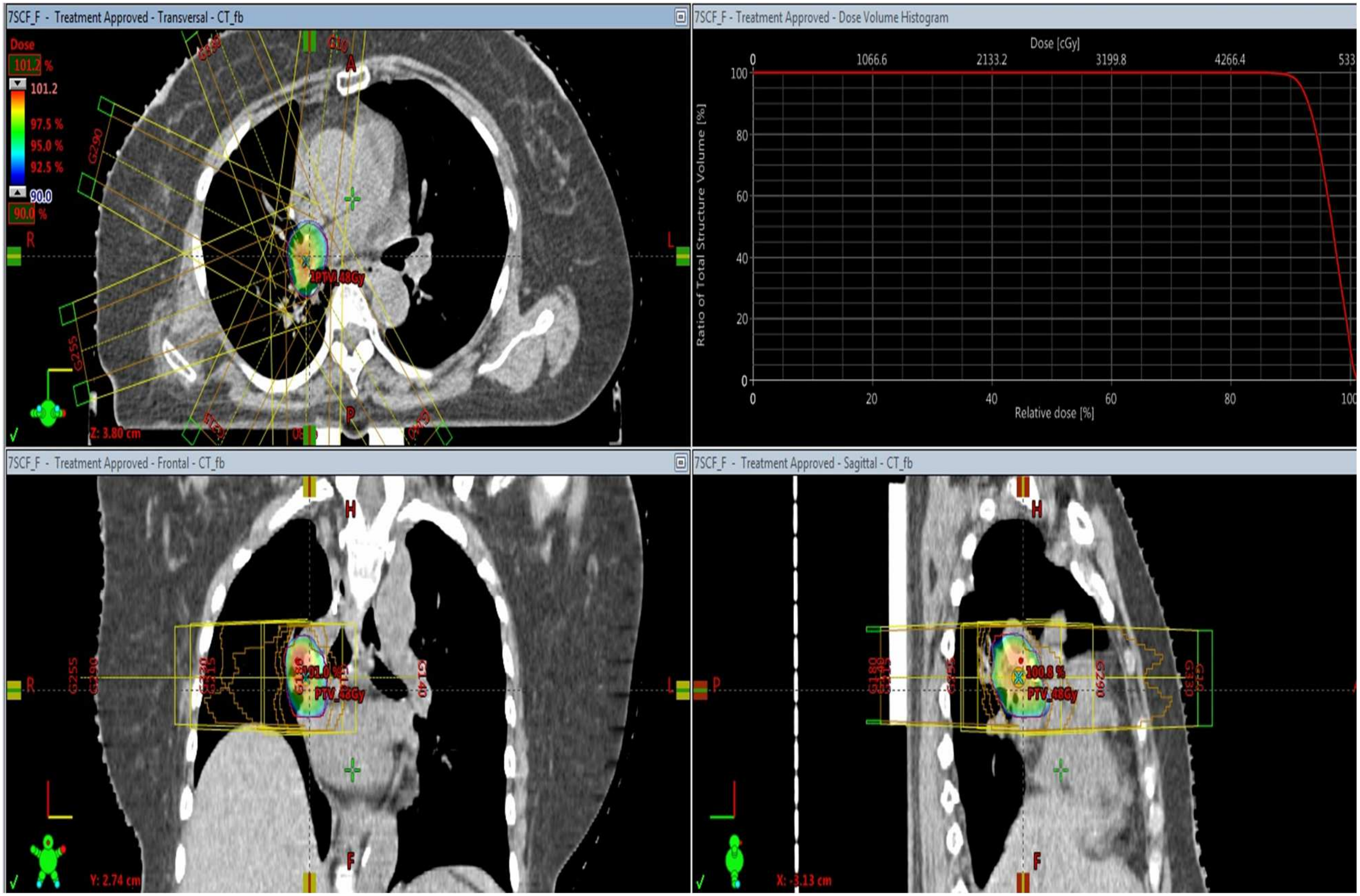




SBRT – Liver and Diaphgram



SBRT - Lung



7SCF_F - Treatment Approved - Transversal - CT_fb
7SCF_F - Treatment Approved - Dose Volume Histogram
Dose [cGy]
0
1066.6
2133.2
3199.8
4266.4
Ratio of Total Structure Volume [%]
Relative dose [%]
7SCF_F - Treatment Approved - Frontal - CT_fb
7SCF_F - Treatment Approved - Sagittal - CT_fb
Dose
101.2
97.5 %
95.0 %
92.5 %
90.0
PTV_48Gy
Z: 3.80 cm
Y: 2.74 cm
X: -3.13 cm

THANK YOU