



Conformal Radiation Therapy- 3D CRT AND IMRT

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Radiation Therapy

Despite advancement from KV X-ray machines to MV linear accelerators, basic approach to RT planning & delivery has remained relatively unchanged.

Radiotherapy is delivered conventionally using limited set of beams.



LIMITATIONS OF CONVENTIONAL RT

1. Uncertainties in delineation of true spatial extent of disease
2. Inadequate knowledge of exact shape & location of normal structures.
3. Lack of tools for efficient planning & delivery
4. Limitations in producing optimal dose distributions.

These limitations results in

1. Incorporation of large safety margins
2. Tumor dose often has to be compromised to prevent normal tissue complications leading to higher probability of local failures

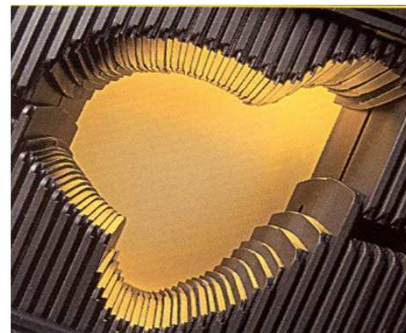
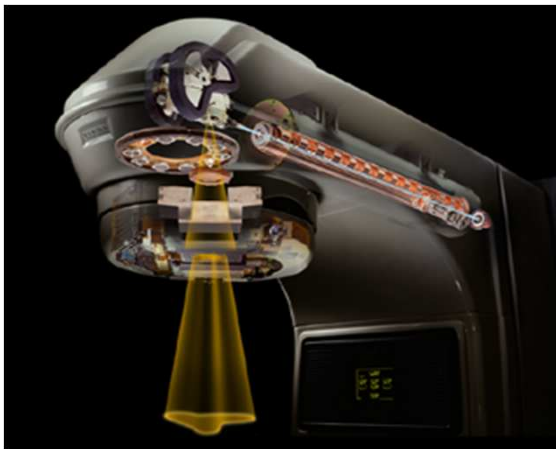


CONFORMAL RADIOTHERAPY

To “concentrate” the radiation in the tumour while sparing normal structures

Conformal RT became achievable because of

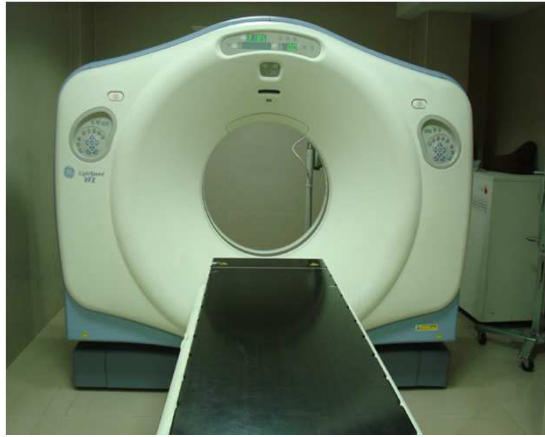
1. Introduction of Multileaf Collimator
2. Synergistic advances in mathematics & computers
3. 3D imaging modalities
4. Computerized therapy planning techniques & dose delivery machines



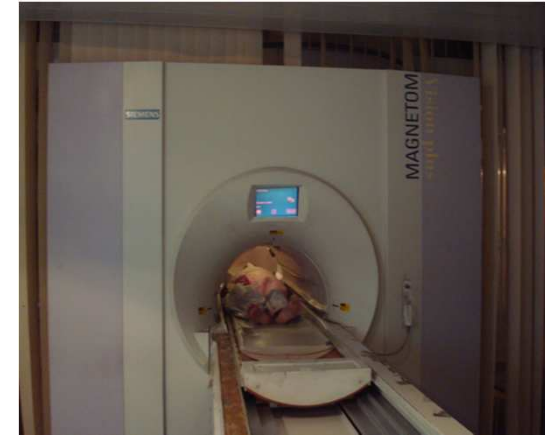


High Tech Diagnostic Machines

CT Simulator



MRI



PET Scan





High Tech Radiotherapy Machines

High Energy Linear Accelerator

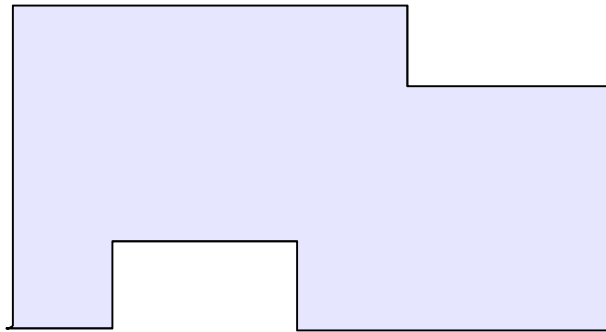


Helical Tomotherapy

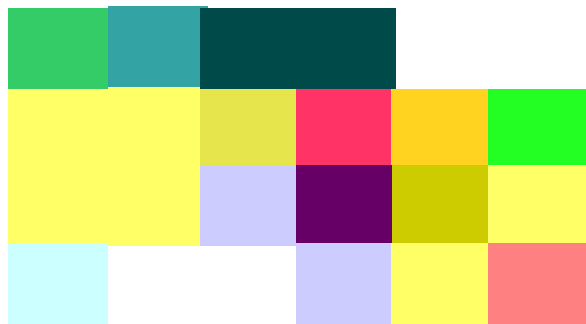




Types of Conformal Radiation



Geometrical Field shaping



Geometrical Field shaping with Intensity 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**)

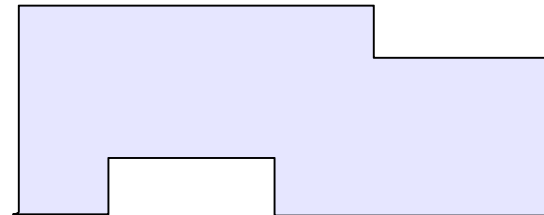


WHAT IS 3-D CRT

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.



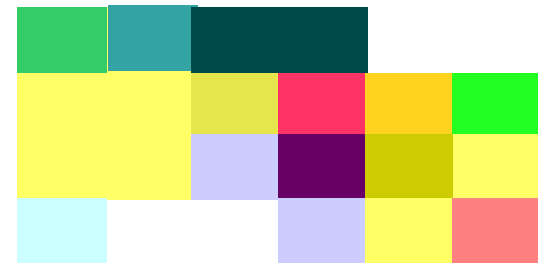
IMRT

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.





ADVANTAGES OF IMRT

IMRT is used

To improve target dose uniformity

To selectively avoid critical structures & normal tissues.

To deliver higher than conventional doses.

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

Focal dose escalation to specific sub volumes in the target vol.
i.e. SIB

Better sparing of critical structures specially during reirradiation.



Caveats: Conformal Therapy

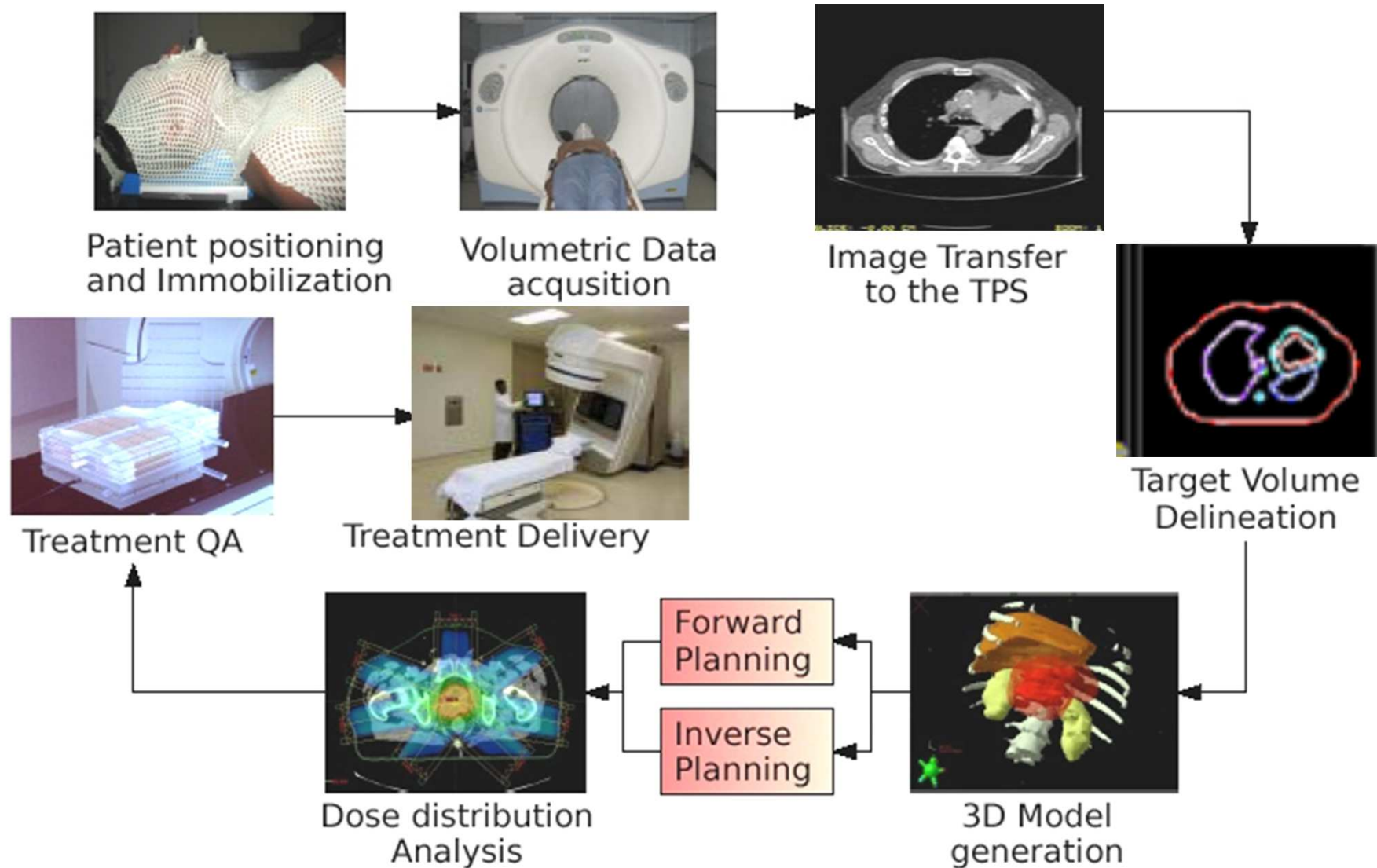
- Significantly **increased** expenditure:
 - Machine with conformal treatment capability
 - Advanced Imaging equipment: Planning and Verification
 - Software and Computer hardware
- Extensive physics manpower and time is required.
- Conformal nature – highly susceptible to motion and setup related errors – Achilles heel of CFRT
- Target delineation remains problematic.
- Treatment and Planning time both significantly increased
- Radiobiological disadvantage:
 - Decreased “dose-rate” to the tumor
 - Increased integral dose (Cyberknife > Tomotherapy > IMRT)



TREATMENT PLANNING FOR CONFORMAL TECHNIQUES



WORKFLOW OF CONFORMAL RT





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 ACQUISITION

- 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



CT IMAGING

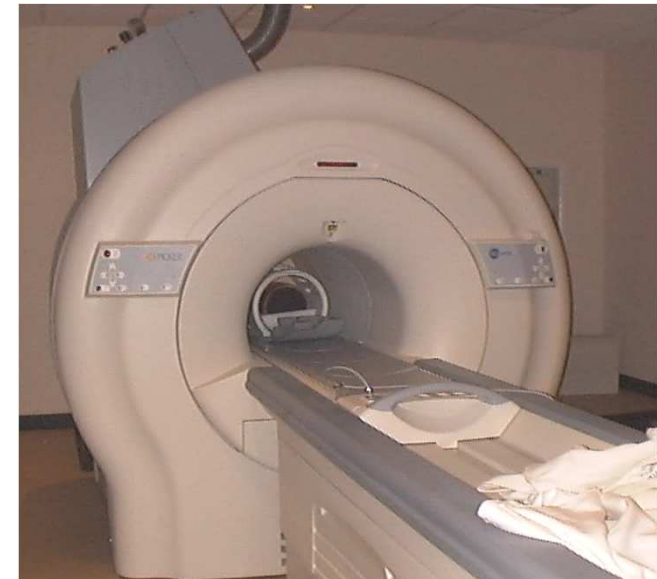
- Advantages of CT
 - Gives quantitative data in form of CT no. (electron density) to account for tissue heterogeneities while computing dose distribution.
 - Gives detailed information of bony structures
 - Potential for rapid scanning
 - 4 -D imaging can be done.
 - Widely available; (relatively) inexpensive





MRI IMAGING

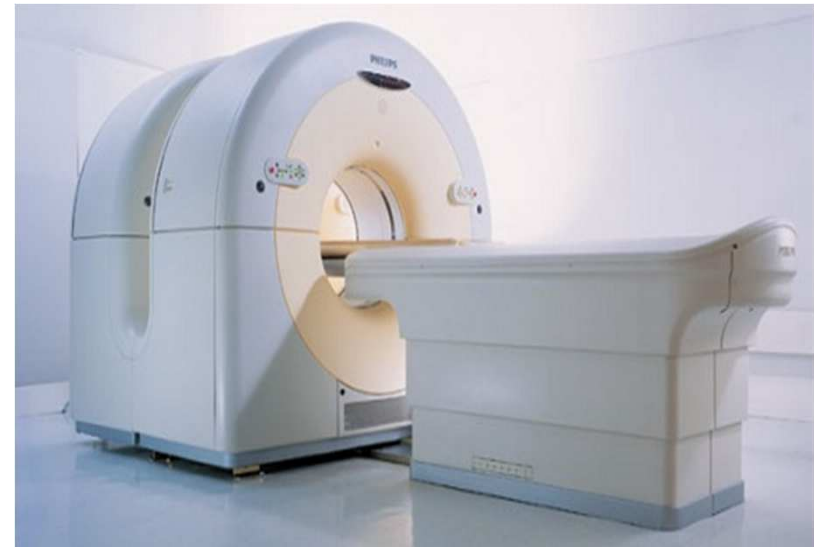
- Advantages of MRI
 - No radiation dose to patient
 - Unparalleled soft tissue delineation
 - scans directly in axial, sagittal, coronal or oblique planes
 - Vascular imaging with contrast agents





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 at the presumed isocentre.
- 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.



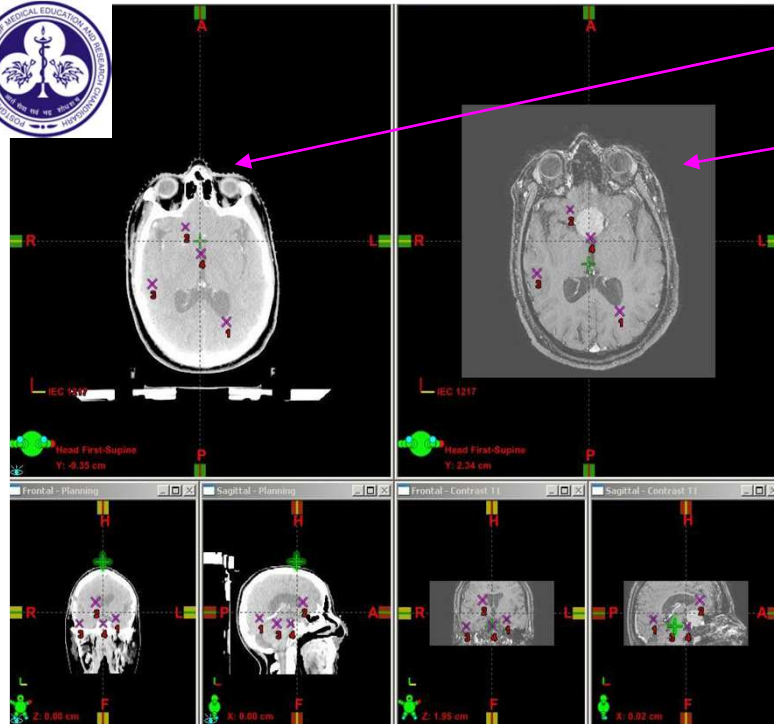
TREATMENT PLANNING SYSTEM

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



IMAGE REGISTRATION

- Image 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

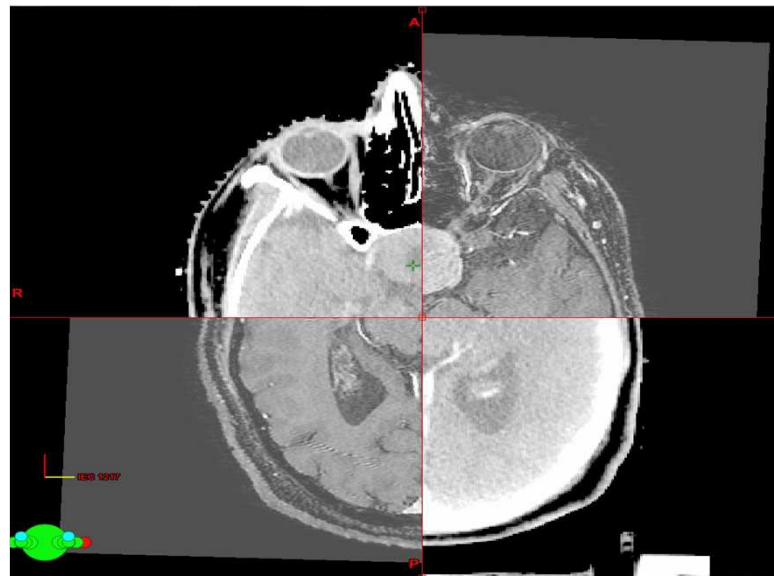
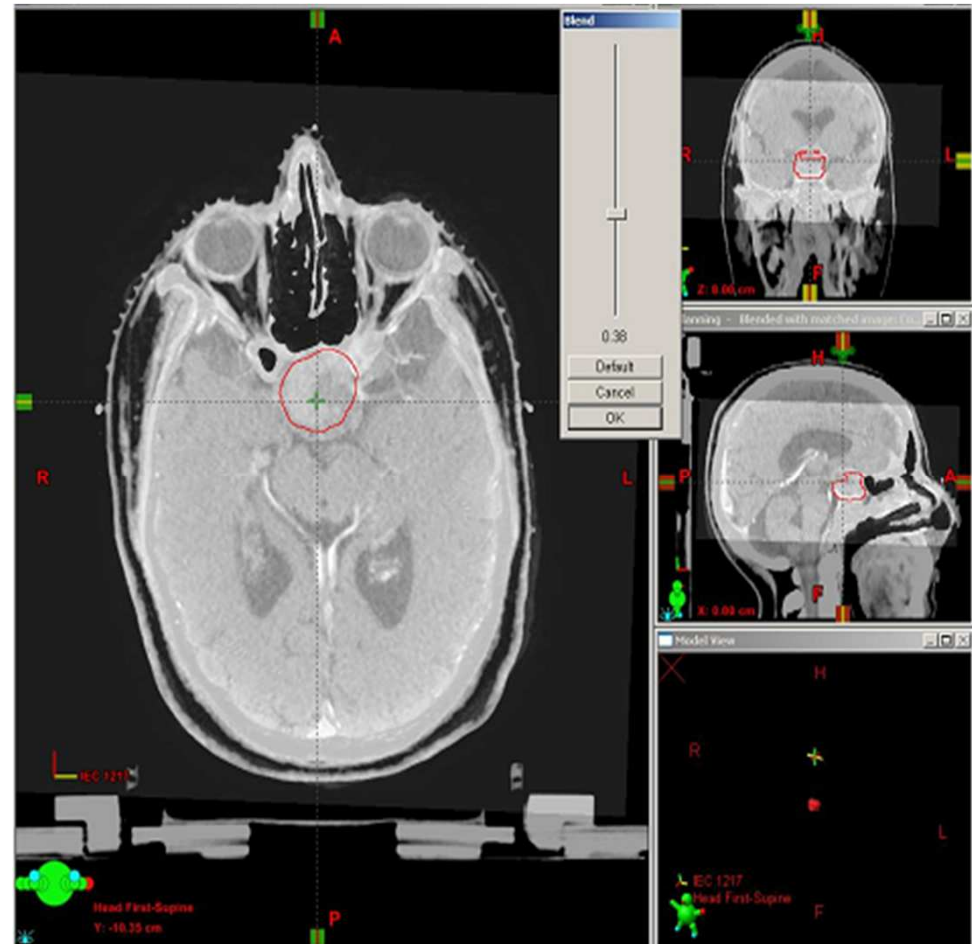


IMAGE FUSION



CONTOURING ON BLENDED IMAGE



APPLICATIONS OF IMAGE REGISTRATION

- Identifying the volume of a tumour on a preoperative scan and transferring it to the postoperative treatment planning scan to define the target volume.
- Visualizing CNS structures more clearly seen on MRI and mapping them to CT image for planning-fusion
- Combining functional or biochemical signals from emission tomography onto CT scans for planning purposes.
- For organ motion studies
- Image guidance
- For follow-up studies
- 4D CT
- Image registration allows computation of cumulative doses from multiple plans done on different image sets for same patient



IMAGE SEGMENTATION OR CONTOURING

- Most labour-intensive component of 3-D CRT
- Necessary for the qualitative and quantitative evaluation of treatment plan.
- Reconstructed sagittal & coronal images provide additional orientation cues & are useful in defining spatially consistent volumes of interest.
- Segmentation is done manually or automatically delineating anatomic regions of interest on a slice-by-slice basis

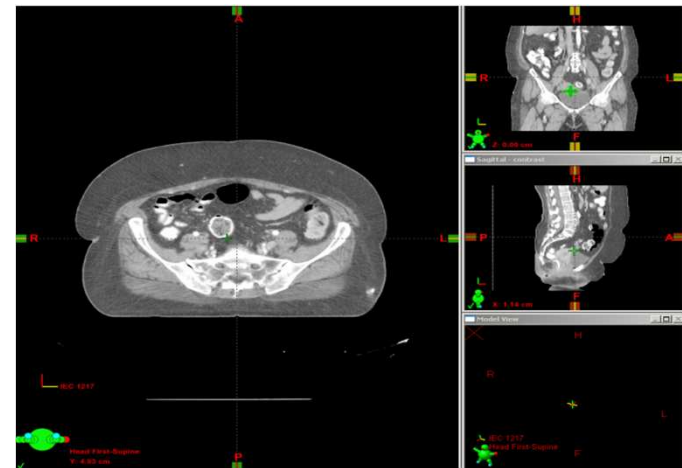
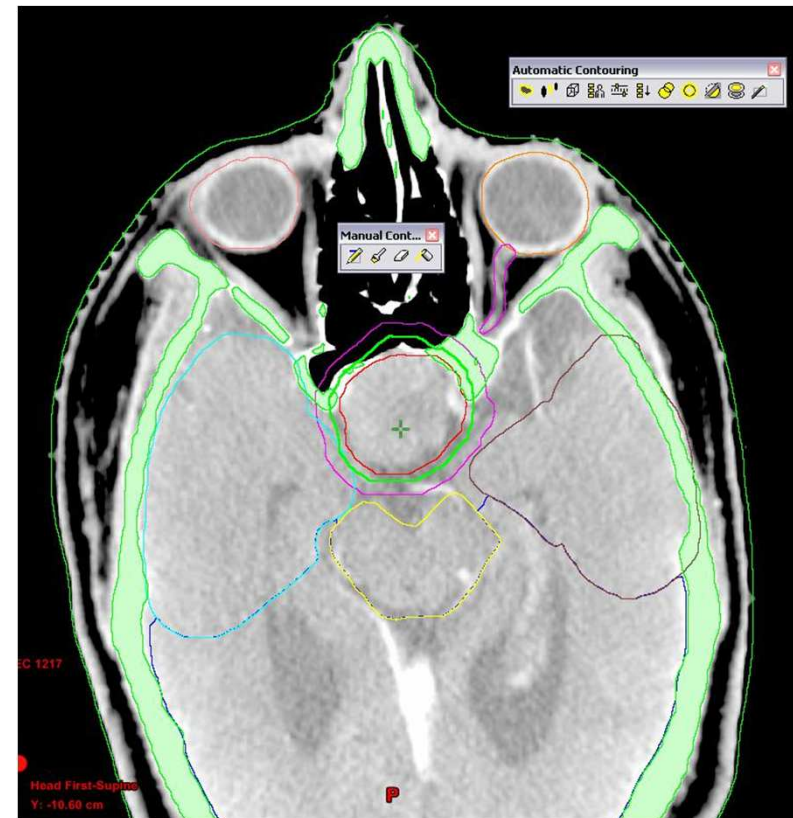




IMAGE SEGMENTATION

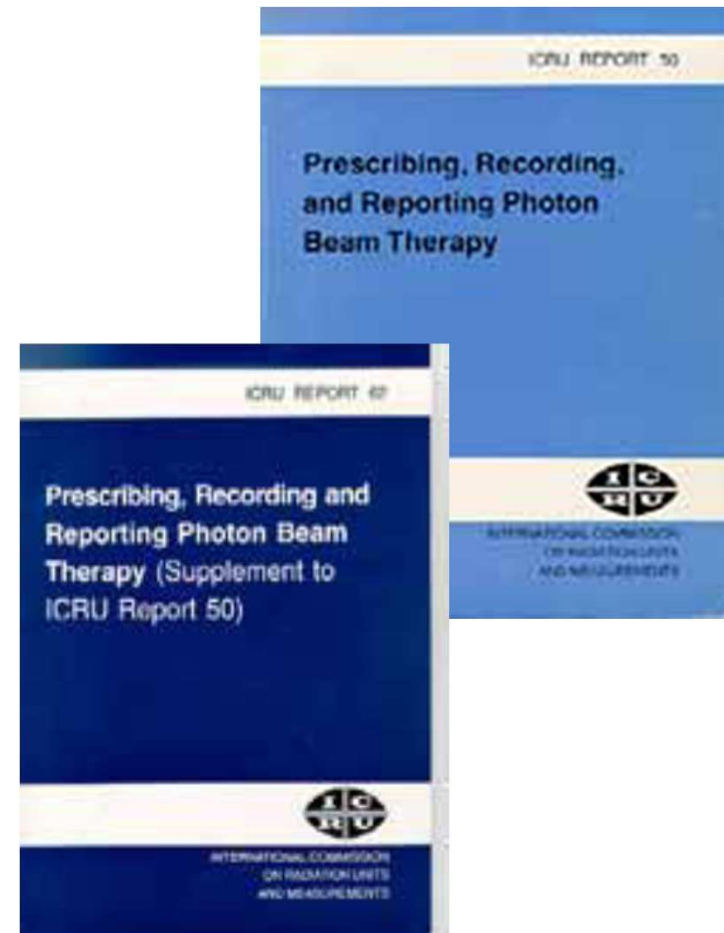
- The segmented regions can be rendered in different colors.
- High contrast structures e.g. lungs, bones & air cavities can be contoured with edge detection & edge tracking techniques.
- The computer automatically tracks path of a specified pixel value & connects the pixels into a contour outline
- Basic features of contouring software are manipulating image contrast and brightness, zoom, pan, sampling pixel values, distance measurement.
- Contours drawn on a limited number of widely separated image sections can be interpolated





VOLUME DEFINITION

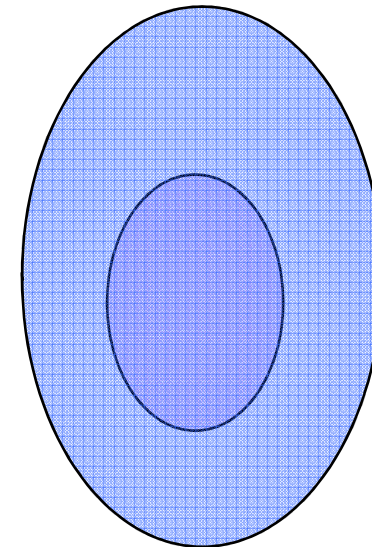
- Volume definition is prerequisite for 3-D treatment planning.
- To aid in the treatment planning process & provide a basis for comparison of treatment outcomes.
- ICRU reports 50 & 62 define & describe target & critical structure volumes.





VOLUME DEFINITION

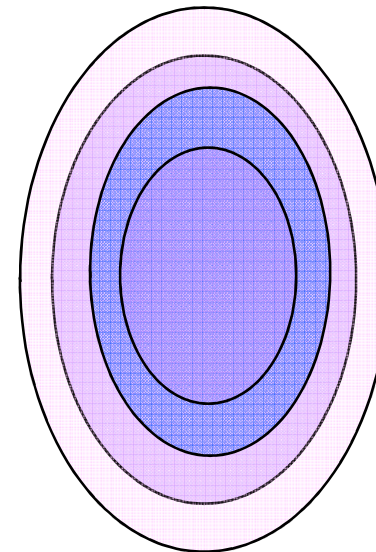
- **The Gross Tumor Volume (GTV)** - is gross palpable or visible/demonstrable extent and location of malignant growth
- defined with the help of
 - Imaging modalities & clinical examination
- **The Clinical Target Volume (CTV)** - is tissue volume that contains GTV and/or sub-clinical microscopic malignant disease, which must be eliminated.
- This volume thus has to be treated adequately in order to achieve the aim of therapy, cure or palliation.





VOLUME DEFINITION

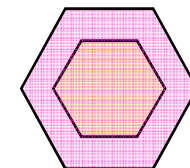
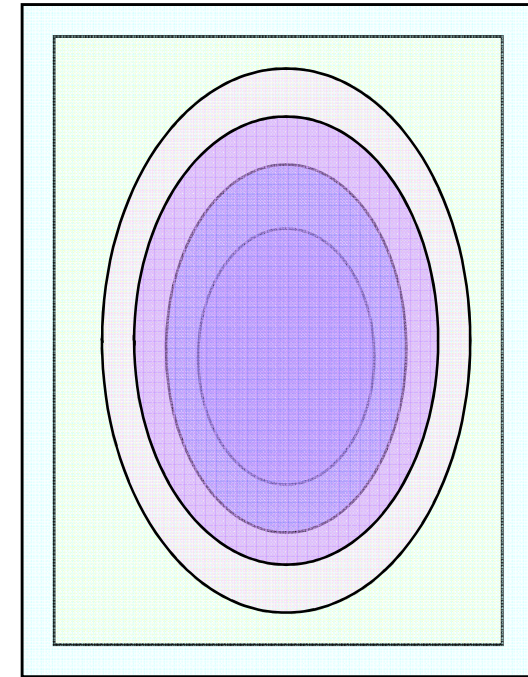
- **ITV-Internal target volume** consists of CTV plus internal margin.
- Internal margin accounts for variations in the size & position of CTV relative to the patient's reference frame (usually defined by the bony anatomy), i.e., variations due to organ motion, such as breathing, bladder or rectal contents, etc.
- **PTV-Planning target volume** includes the internal target margin & an additional margin for:
 - Set-up uncertainties
 - Machine tolerances
 - Intra-treatment variations
- The PTV does NOT include a margin for dosimetric characteristics of the radiation beam.





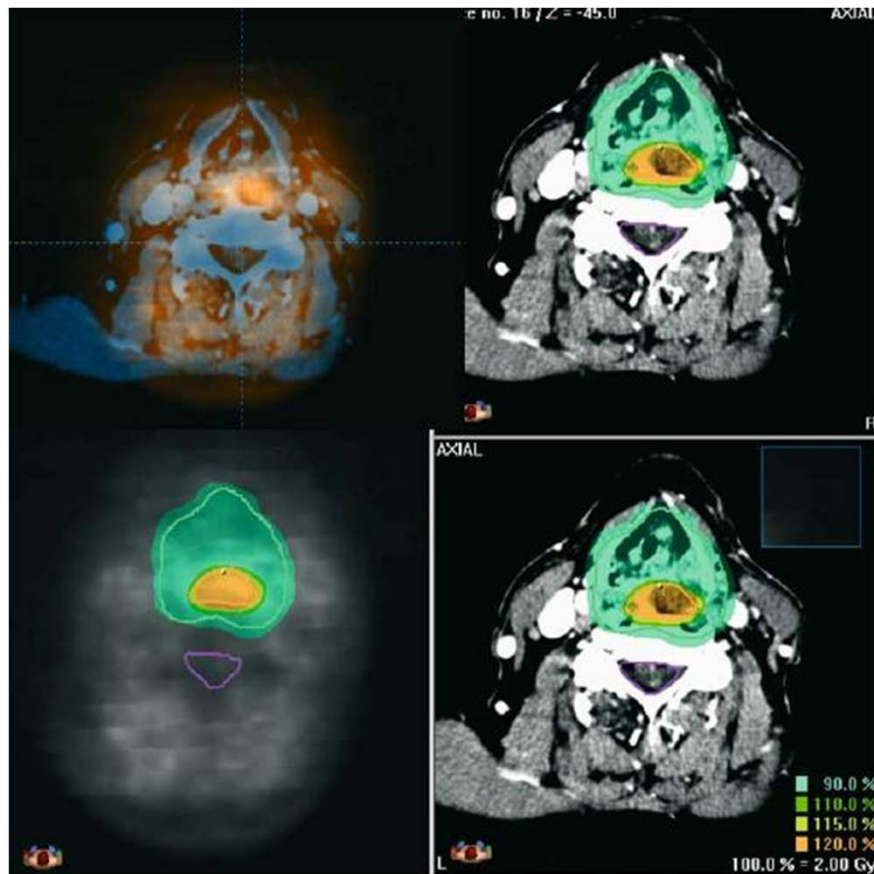
VOLUME DEFINITION

- **Organ at Risk (OAR)** - is an organ whose sensitivity to radiation is such that the dose received from a treatment plan may be significant compared to its tolerance, possibly requiring a change in beam arrangement or a change in dose.
- **PVR- planning organ at risk volume** margins need to be added to compensate for its movements, internal as well as set-up.
- **The treated volume** - volume enclosed by an isodose surface that is selected and specified by the Radiation Oncologist as being appropriate to achieve the purpose of treatment (e.g., 95% isodose surface)
- **The irradiated volume** - volume that receives a dose considered significant in relation to normal tissue tolerance.





Biological Target Volume



- A target volume that incorporated data from molecular imaging techniques
- Target volume drawn incorporates information regarding:
 - Cellular burden
 - Cellular metabolism
 - Tumor hypoxia
 - Tumor proliferation
 - Intrinsic Radioresistance or sensitivity



Biological Target Volumes

- **Lung Cancer:**
 - 30 -60% of all GTVs and PTVs are changed with PET.
 - Increase in the volume can be seen in 20 -40%.
 - Decrease in the volume in 20 – 30%.
 - Several studies show significant improvement in nodal delineation.
- **Head and Neck Cancer:**
 - PET fused images lead to a change in GTV volume in 79%.
 - Can improve parotid sparing in 70% patients.



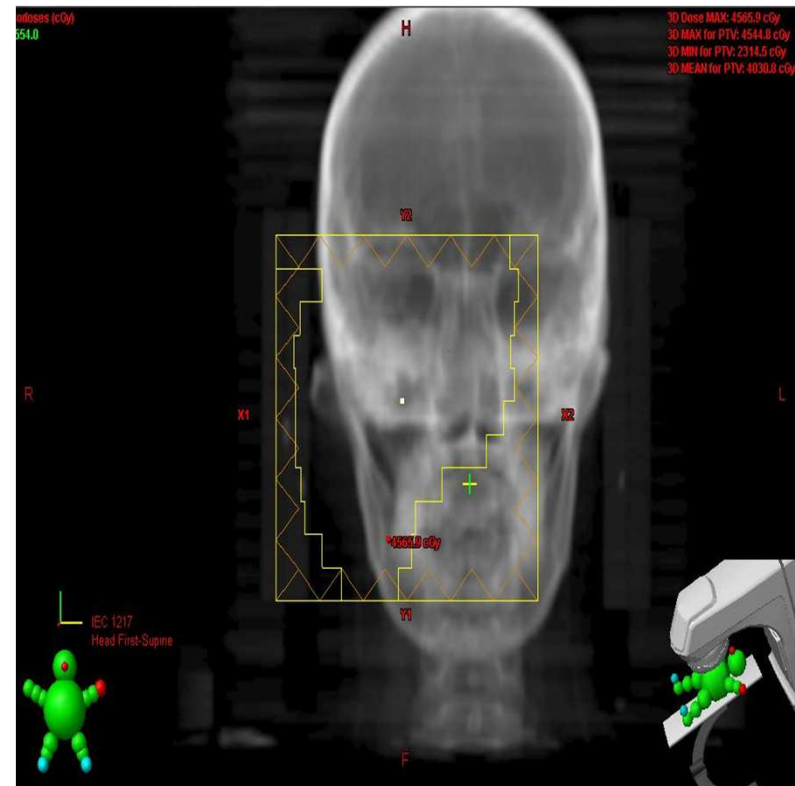
OAR TYPES

- Organs are made up of functional units.
- Radio sensitivity of an organ is determined by the arrangement of these units.
- If functional units are arranged in series then inactivation of one subunit causes loss of function of whole organ –spinal cord
- In parallel organization of functional subunits, inactivation of a large no. of subunits doesn't affect overall organ function.
- Consequently,
 - an organ with high tolerance may be lost by inactivation of a small part.
 - While an organ with very low tolerance may sustain loss of even large no. of subunits.



Digitally Reconstructed Radiograph- DRR

- A synthetic radiographs produced by tracing ray-lines from a virtual source position through the CT data to a virtual film plane .
- It is analogous to conventional simulation radiographs.
- **DRR is used**
 - for treatment portal design
 - for verification of treatment portal by comparison with port films or electronic portal images
 - provides planar reference image for transferring 3D treatment plan to clinical setting





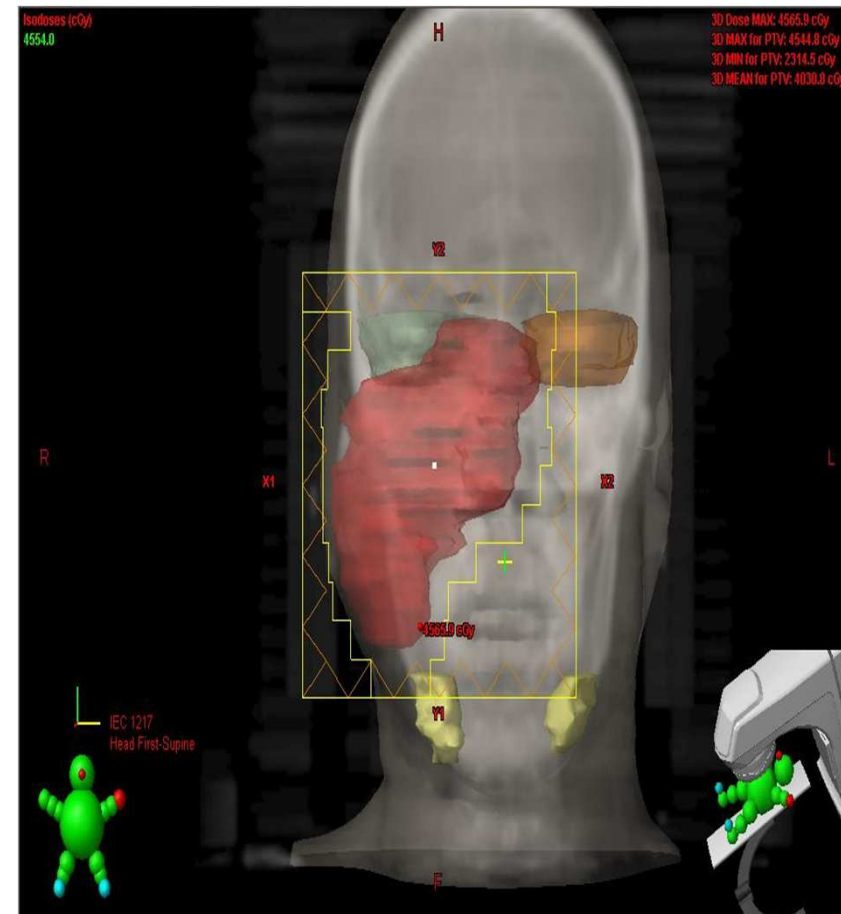
Digitally Composite Radiograph - DCR

- The digitally composite radiograph is a type of DRR that allows different ranges of CT numbers related to a certain tissue type to be selectively suppressed or enhanced in the image.



Beam Eye View-BEV

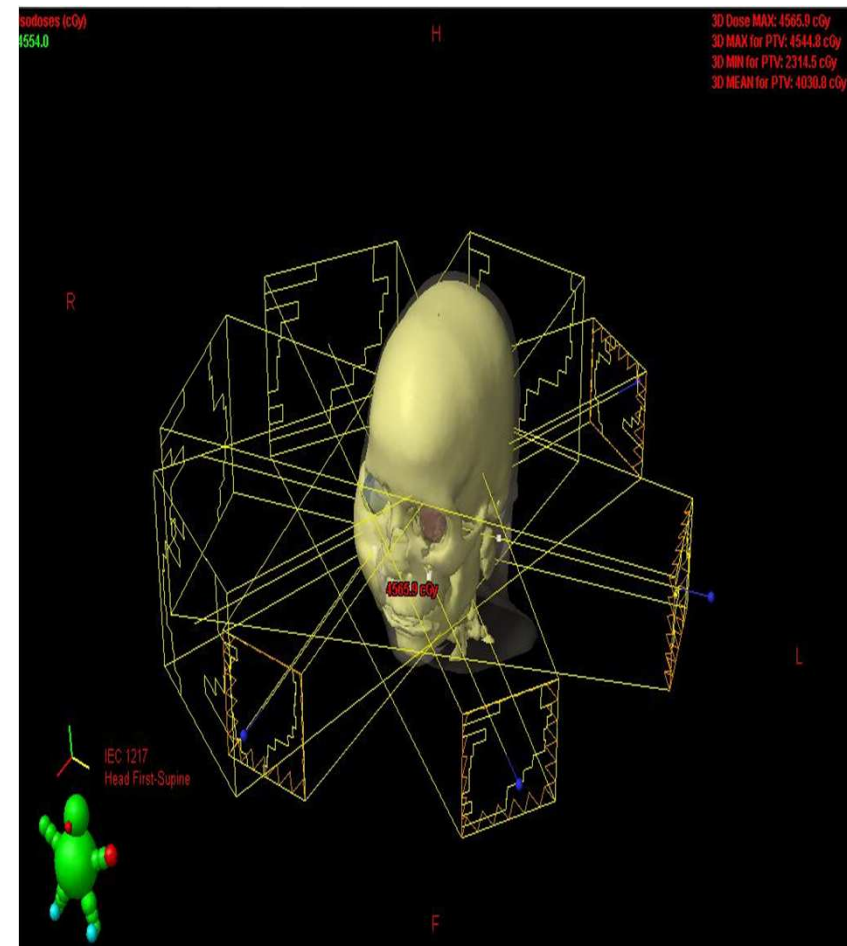
- In BEV observer's viewing point is at the source of radiation looking out along axis of radiation beam.
 - Demonstrates geometric coverage of target volume by the beam
 - Shielding & MLCs are designed on BEV
 - Useful in identifying best gantry, collimator, and couch angles to irradiate target & avoid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

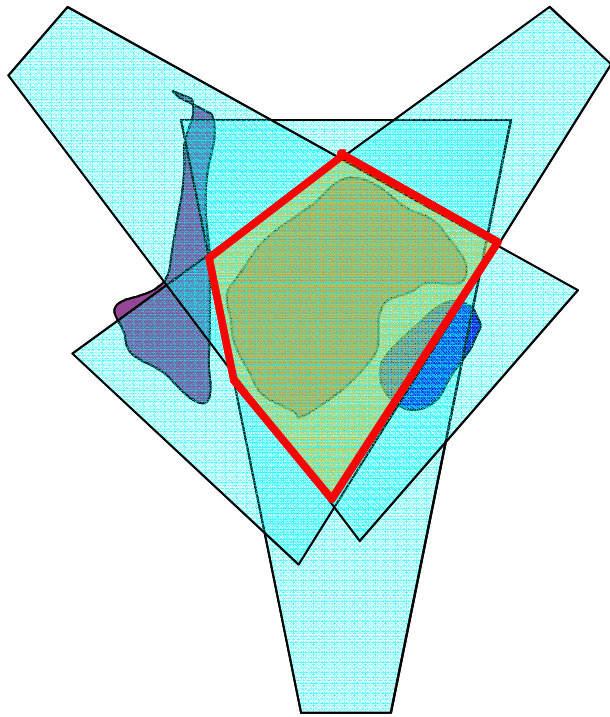


IMRT PLANNING

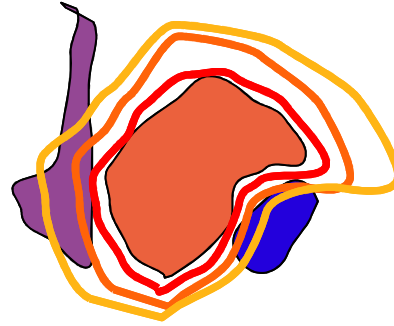
- IMRT planning is an **inverse planning**.
- It is so called because this approach starts with desired result (a uniform target dose) & works backward toward incident beam intensities.
- After contouring, treatment fields & their orientation (beam angle) around patient is selected.
- Next step is to 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



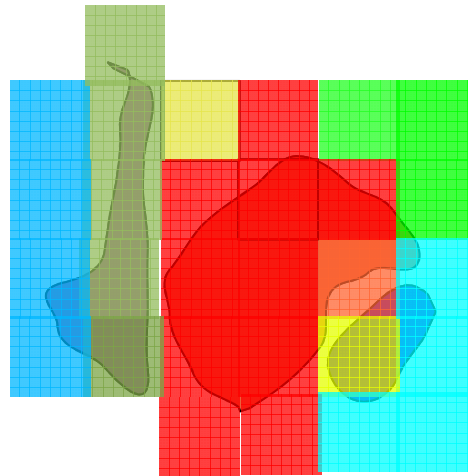
“Inverse” Planning



Forward Planning

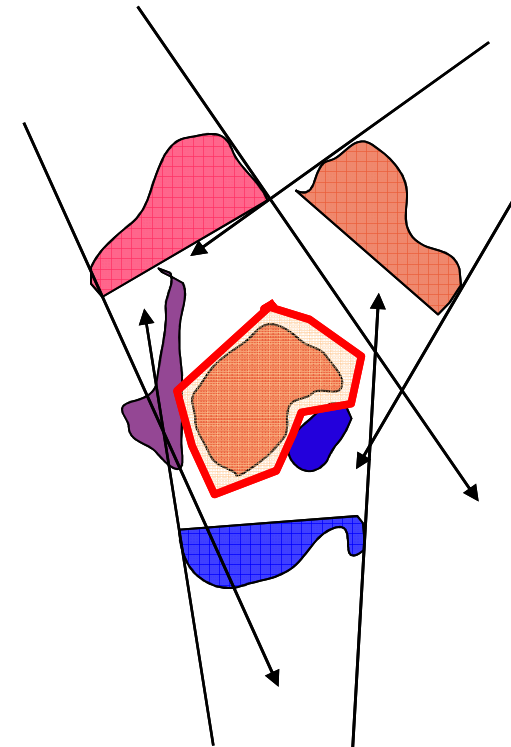


1. Dose distribution specified



2. Intensity map created

Inverse Planning



3. Beam Fluence modulated to recreate intensity map



IMRT PLANNING

- 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.



OPTIMIZATION

- 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



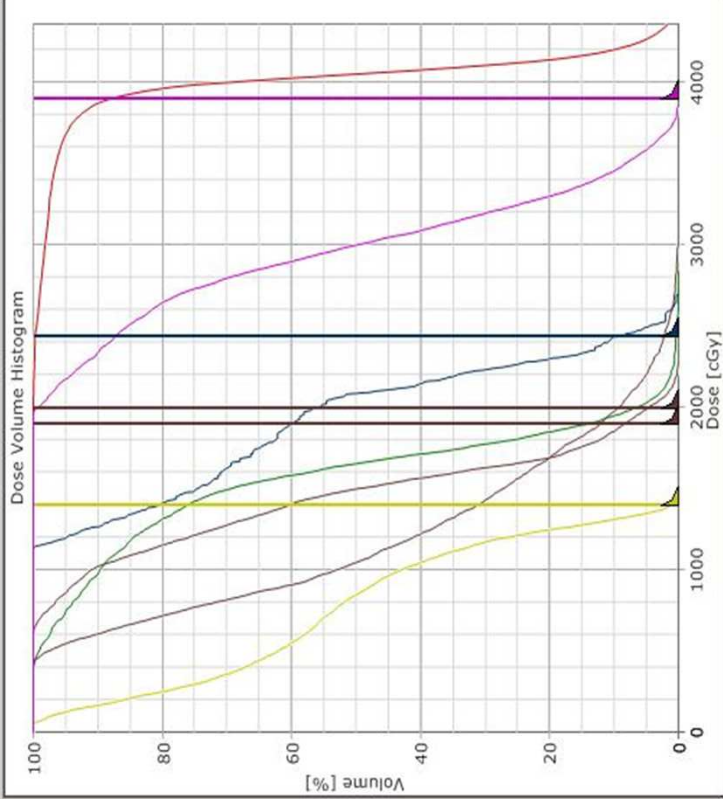
End Objectives

Use Normal Tissue Objective

Normal Tissue Objective Parameters...

Priority: 0

Volume [cc]	Points	Resolution [mm]	Priority
BODY	4040	44769	10.00
D_PTV	355	20898	3.00
Upper	0.0	4100.0	200
Lower	100.0	4000.0	210
D_ll_Temp_Lobe	45	3632	2.73
Upper	0.0	3400.0	110
D_oral_cavity	75	5099	3.00
Upper	0.0	2000.0	250
D_rt_Parotid	1	879	1.00
D_rt_Temp_Lobe	40	3580	2.63
Upper	0.0	3400.0	110
Dose 107%	2	1538	1.00
GTV	228	14288	3.00
L_SMG	6	2291	1.38
L temporal lobe	52	3756	2.85
Margin	524	12098	6.00
PTV	352	20578	3.00
R_SMG	5	2228	1.29
R temporal lobe	51	3662	2.84
bones	751	106665	3.00
l ear	4	2211	1.19
Upper	0.0	1900.0	100
l eye	11	2913	1.68
Upper	0.0	1900.0	100



MLC	Method	X Smooth	Y Smooth	Minimize Dose	Fixed Jaws	Field Weight
Field 1	MLC-2300CD	80	60	0		1.000
Field 2	MLC-2300CD	80	60	0		1.000
Field 3	MLC-2300CD	80	60	0		1.000
Field 4	MLC-2300CD	80	60	0		1.000
Field 5	MLC-2300CD	80	60	0		1.000
Field 6	MLC-2300CD	80	60	0		1.000
Field 7	MLC-2300CD	80	60	0		1.000

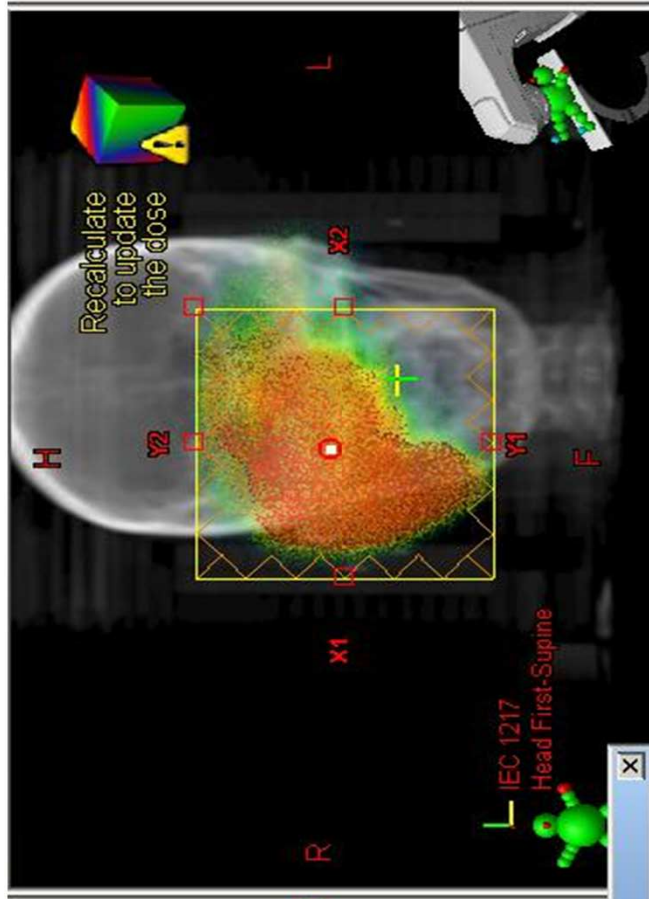
Base dose plan:

Optimizing 0h 1m 38s 16

Max time (min): 100
Max iterations: 1000

Buttons: OK, Cancel, Apply, Stop

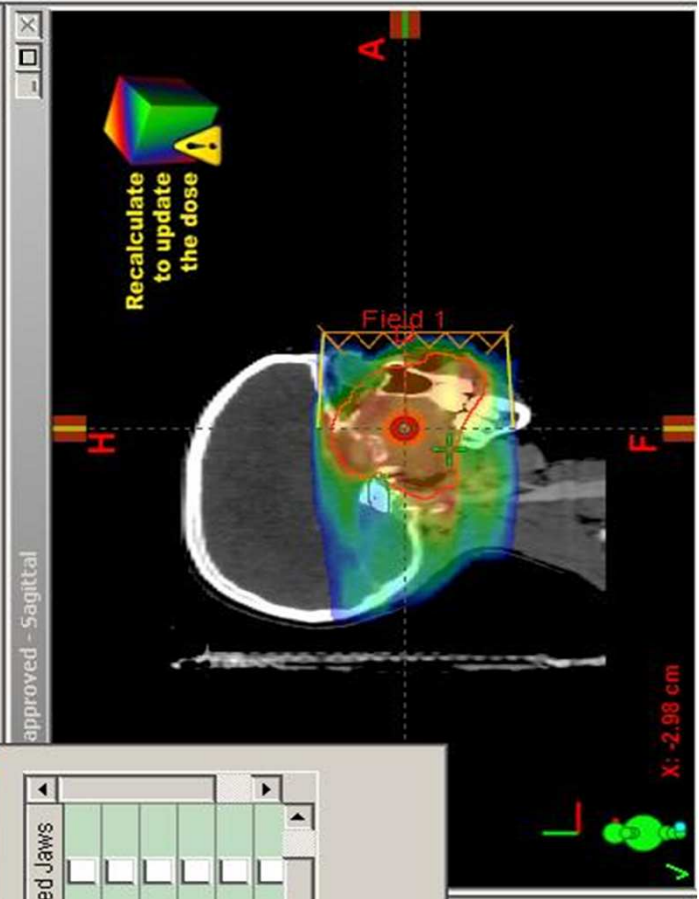
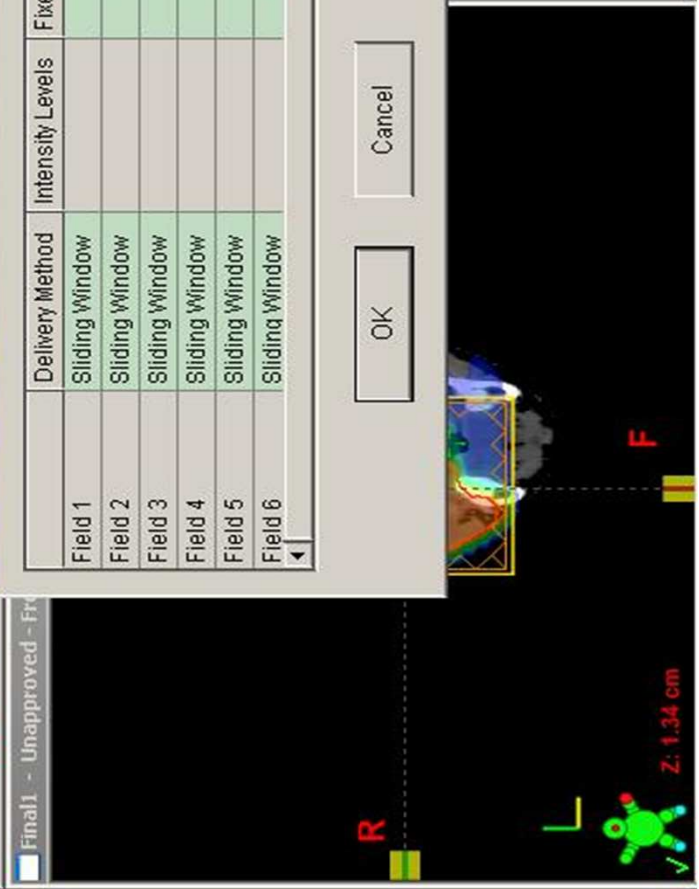
View with interpolation
Use color



Leaf Motion Calculation Options

	Delivery Method	Intensity Levels	Fixed Jaws
Field 1	Sliding Window		<input type="checkbox"/>
Field 2	Sliding Window		<input type="checkbox"/>
Field 3	Sliding Window		<input type="checkbox"/>
Field 4	Sliding Window		<input type="checkbox"/>
Field 5	Sliding Window		<input type="checkbox"/>
Field 6	Sliding Window		<input type="checkbox"/>

OK Cancel





Optimization Criteria

- Refers to the **constraints** that need to be fulfilled during the planning process
- **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.



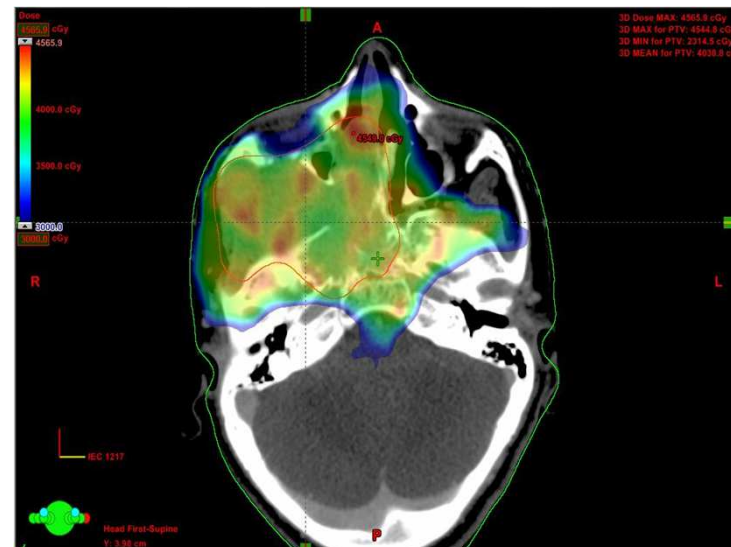
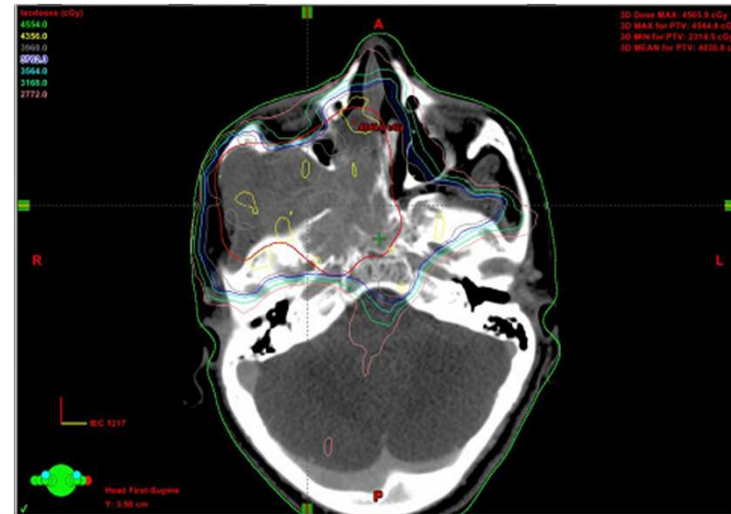
PLAN EVALUATION

- 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.





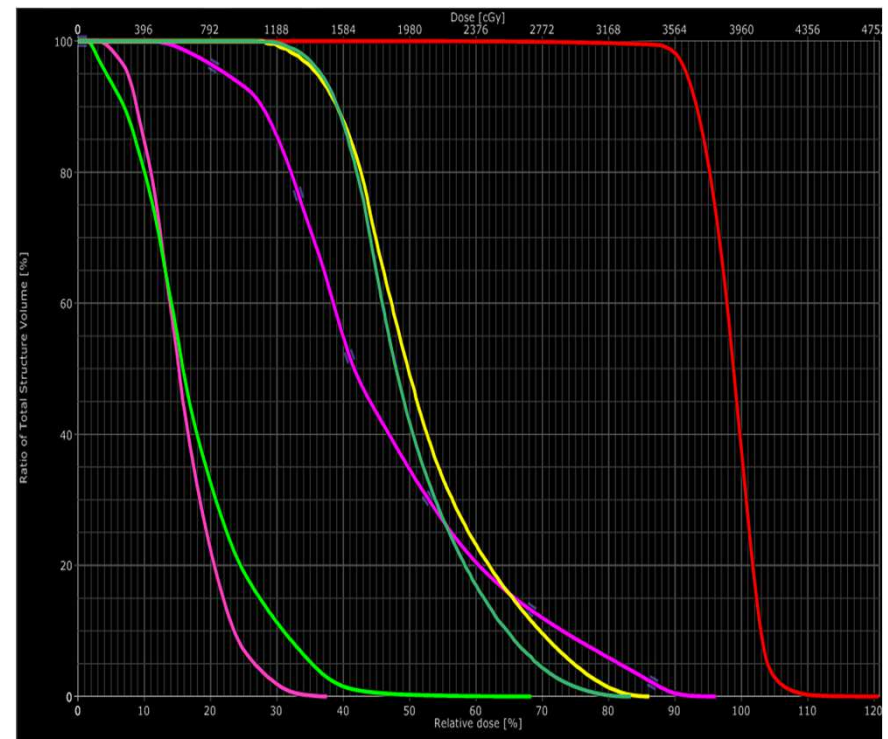
DOSE VOLUME HISTOGRAM - DVH

- 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

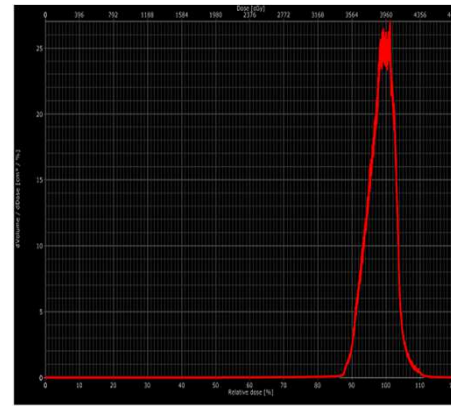
- It is plot of volume of a given structure receiving a certain dose.
- Any point on the cumulative DVH curve shows the volume of a given structure that receives the indicated dose or **higher**.
- It start at 100% of the volume for zero dose, since all of the volume receives at least more than zero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



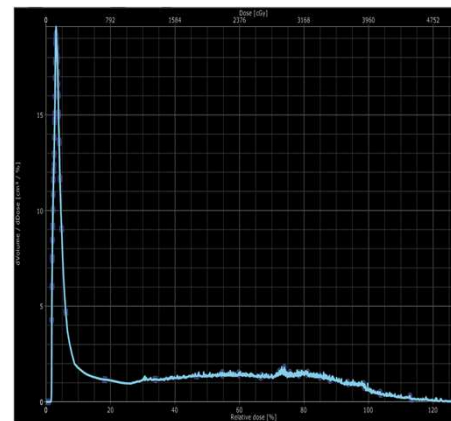


DIFFERENTIAL DVH

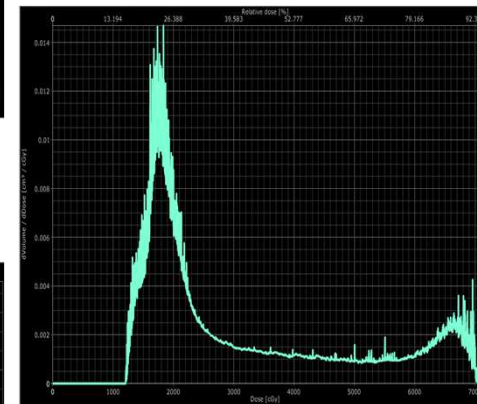
- The direct or differential DVH is a plot of volume receiving a dose within a specified dose interval (or dose bin) as a function of dose.
- It shows extent of dose variation within a given structure.
- The ideal DVH for a target volume would be a single column indicating that 100% of volume receives 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.



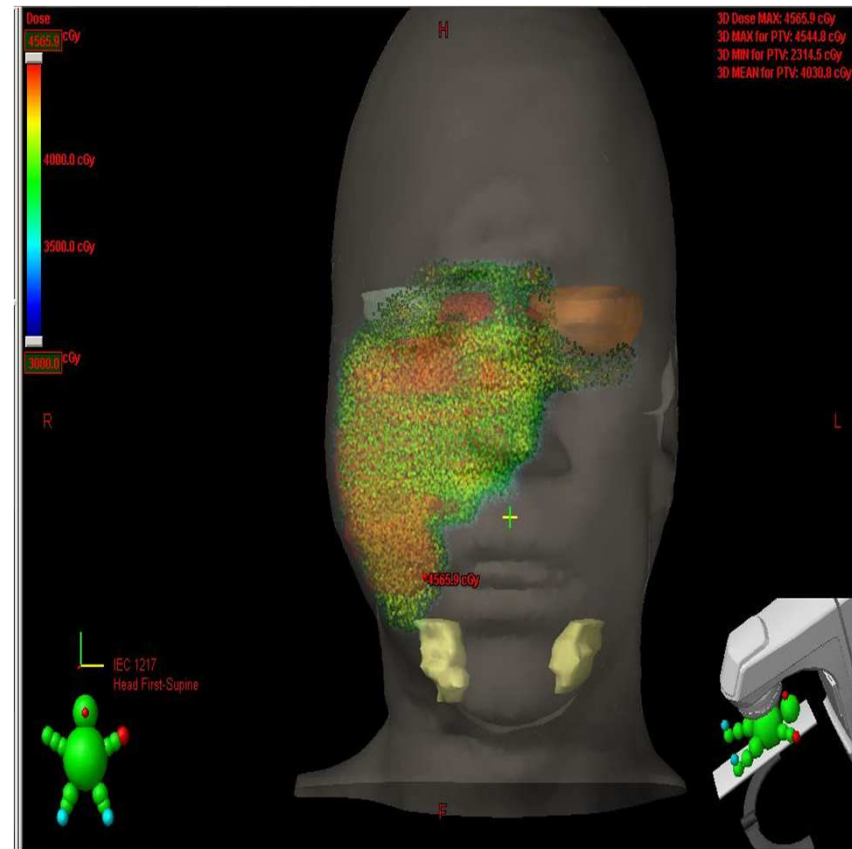
DVH - OAR





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.





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.



PLAN VERIFICATION FOR 3DCRT

- These include
 - An independent check of the plan and monitor unit calculation by a physicist,
 - isocenter placement check on the treatment machine using orthogonal radiographs,
 - field-apertures check using portal films or electronic portal images, and
 - to ensure that input data into the Record & Verification system are correct
 - to confirm the geometric validity and accuracy of the 3D treatment plan.
 - to confirm the correctness of the beam orientations in the physical implementation by taking port film or image & comparing it with DRR.



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



PLAN VERIFICATION

- Specially designed **IMRT phantoms** are used.
- These phantoms have various inhomogeneity built in that allow verification not only of IMRT plans but also of the algorithm used for tissue inhomogeneity corrections.
- It is also possible, however, to use simple phantoms made of Lucite, polystyrene or other water equivalent materials, in which dosimeters can be positioned.



IMRT PHANTOM



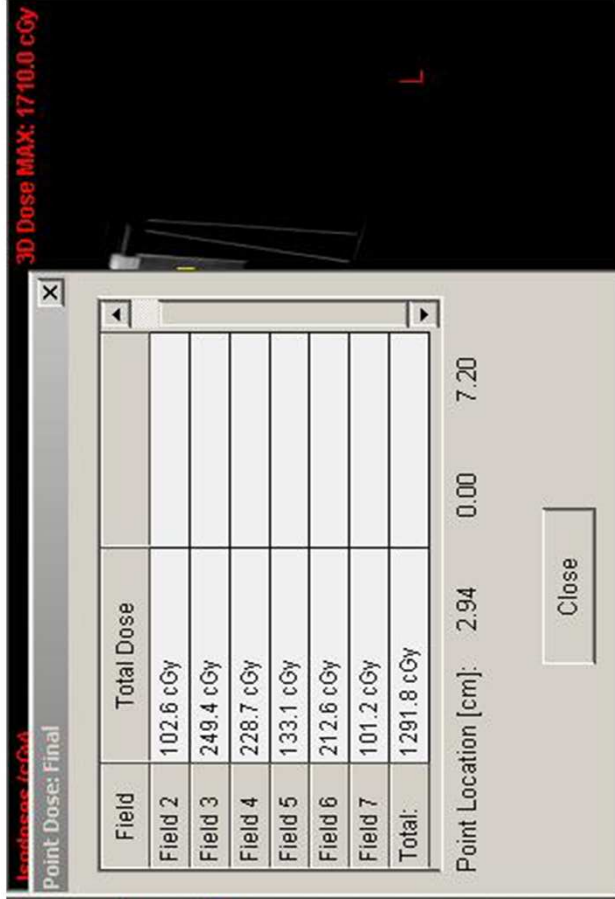
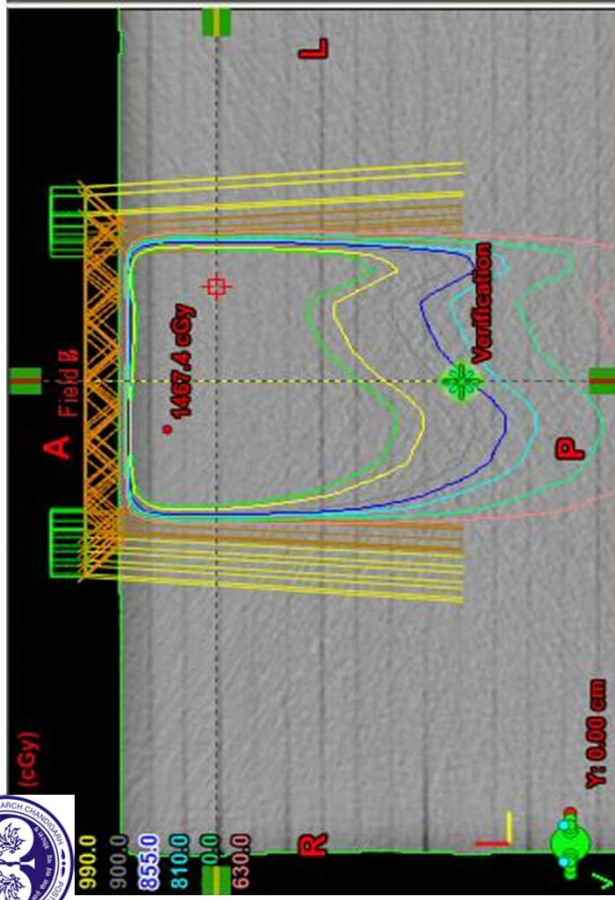
ionamatrixx



PLAN VERIFICATION

- Involves mapping the plan fields onto a phantom, to create a verification plan & comparing the results with measurements made on that phantom.
- Assuming that validity of results for the phantom can be extrapolated to the patient.
- CT images of the IMRT phantom with ionization chamber in the slot, are taken with 2.5mm slice thickness.
- Phantom images are transferred to TPS & body of phantom is contoured.
- A phantom plan is created by superimposing the patient plan on to the IMRT phantom.
- All gantry angles are made to zero-degree orientation for the measurement without changing anything further so that isodose and profile remained the same, & it is called verification plan.





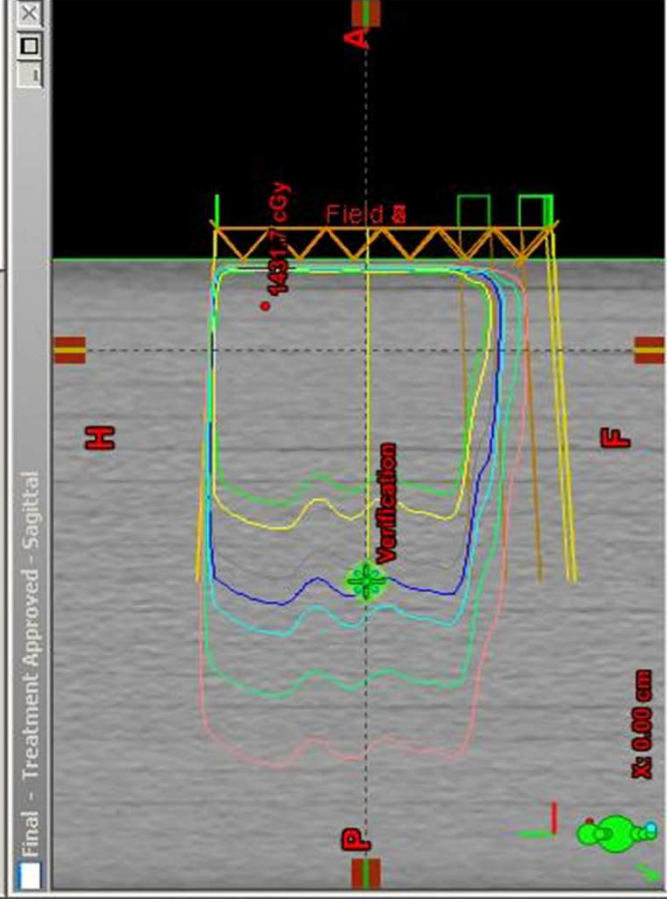
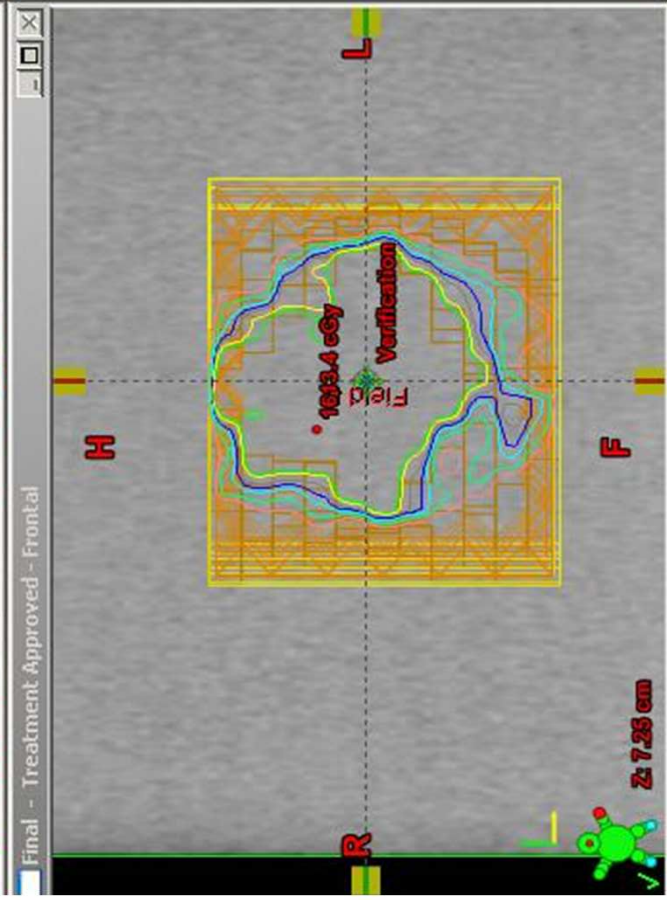
Point Dose: Final

Field	Total Dose
Field 2	102.6 cGy
Field 3	249.4 cGy
Field 4	228.7 cGy
Field 5	133.1 cGy
Field 6	212.6 cGy
Field 7	101.2 cGy
Total:	1291.8 cGy

Point Location [cm]: 2.94 0.00 7.20

Close

3D Dose MAX: 1710.0 cGy





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.
- 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.



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)



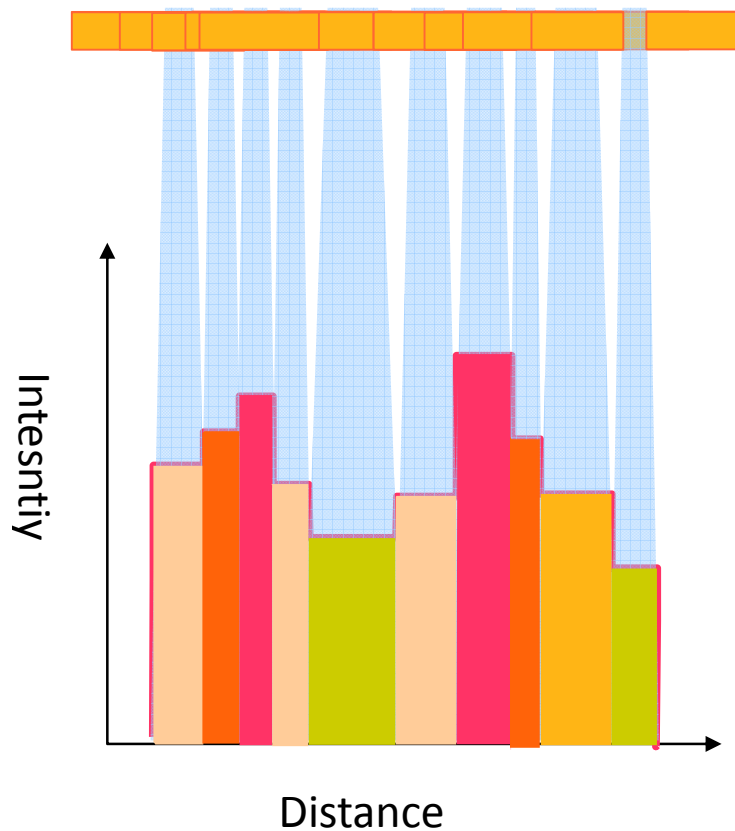
STEP & SHOOT IMRT

- 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





Step & Shoot IMRT



- Since beam is interrupted between movements leakage radiation is less.
- Easier to deliver and plan.
- More time consuming



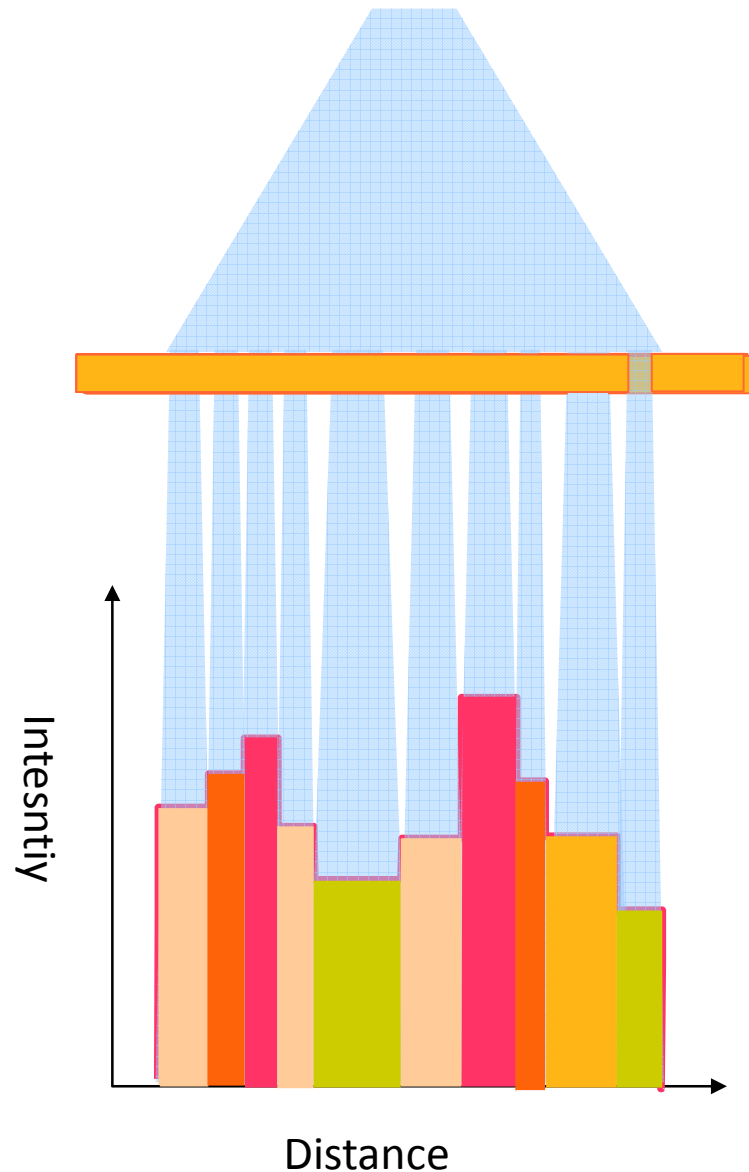
DYNAMIC MODE

- 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





Dynamic IMRT



- Faster than Static IMRT
- Smooth intensity modulation achieved
- Beam remains on throughout – leakage radiation increased
- More susceptible to tumor motion related errors.
- Additional QA required for MLC motion accuracy.



IMAT

- Intensity-modulated arc therapy (IMAT) technique uses MLC dynamically to shape fields as gantry rotate in an arc.
- IMAT, which uses five to seven overlapping concentric arcs to deliver a conformal dose distribution



TOMOTHERAPY

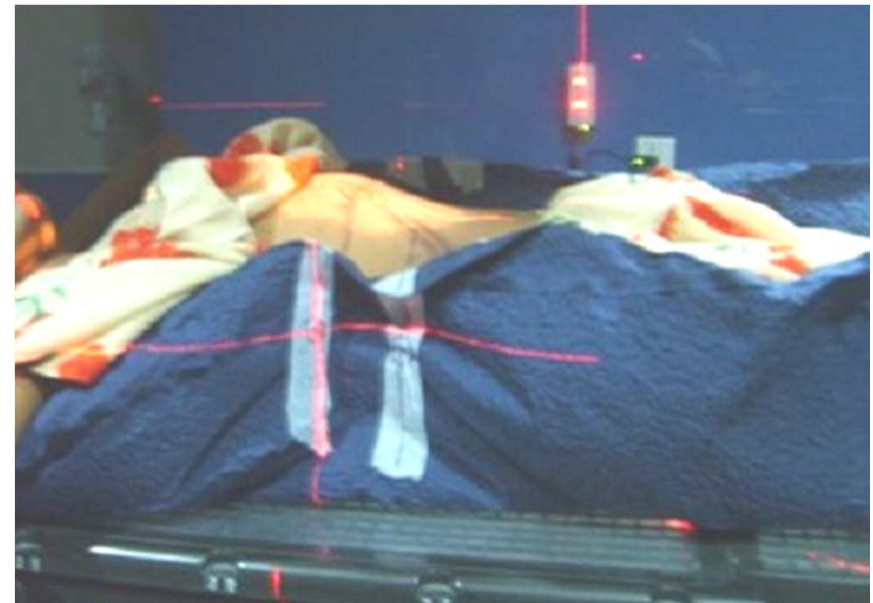
- Historically, IMRT by tomotherapy preceded IMRT by any MLC-based technique.
- Delivered by two methods:
 - Slice based tomotherapy
 - Helical tomotherapy



EXECUTION OF TREATMENT



shifting of coordinates



Aligning the pt. using laser



RESULTS OF CONFORMAL TECHNIQUES IN RADIOTHERAPY



CONFORMAL RADIATION THERAPY

QUESTIONS

1. **Do conformal techniques allow dose escalation ?**
2. **Have conformal techniques increased local control ?**
3. **Have conformal techniques increased survival rates ?**
4. **Have conformal techniques reduced late effects ?**



CONFORMAL RADIATION THERAPY

1. Do conformal techniques allow dose escalation ?

Conformal techniques like 3-D CRT & IMRT has definitely achieved escalation of radiation dose compared to conventional radiotherapy at some sites.

Dose has been increased from conventional 60-65 Gys. to 70-86 Gys., particularly in cancer of prostate and head & neck cancers.



CONFORMAL RADIATION THERAPY

2. Have conformal techniques increased local control ?

Significant dose escalation has been possible so far in the treatment of cancer of Prostate only.

Dose has been increased from 65 – 86 Gys.

Escalation of dose has increased both histological & biochemical local control of prostate cancer.

The effect on survival is not very significant.

Conformal techniques have so far failed to achieve significant dose escalation in other tumours with increase in the local control.



CONFORMAL RADIATION THERAPY

3. Have conformal techniques increased survival rates ?

The 3-D CRT and IMRT has not led to desired & expected increase in the survival rates for various cancers treated by these techniques.

There is only 1-2%age increase in survival compared to conventional radiation therapy.

Inspite of these techniques being introduced in 1980's & early 1990's, clinical results reported are far from few.



CONFORMAL RADIATION THERAPY

4. Have conformal techniques reduced late effects ?

The greatest impact of conformal techniques have been seen in the reduction of late radiation morbidity, which has been reduced by 1/3rd to 2/3rd compared to toxicity produced by conventional radiation therapy.

and

This is the only justification for use of these techniques.

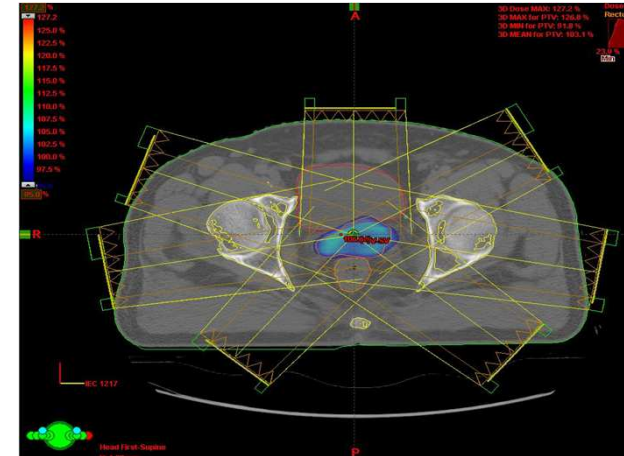


Clinical applications- Prostate

Dosimetric data on Organs at risk

3DCRT can drastically reduce rectal and bladder dose (Perez et al)

	Conv RT	3DCRT
Bladder > 65Gy	~60%	~34%
Rectum > 65Gy	~50%	~22%



➤ Clinical data on Toxicity

Rectal and bladder complication rates are reduced

	Conv. RT	3DCRT	IMRT
GrII	~50-60%	20-30%	5% (R) 15% (B)
GrIII		~3-4%	(20-30% with dose escalation)

Zelevsky et al 2000, 2003, 2005 . IMRT toxicity at 81Gy comparable with 3DCRT to 65-75Gy.



CONFORMAL RADIATION THERAPY

Royal Marsden Hospital, London
Carcinoma Prostate – 3D CRT

Late Toxicity	Conventional RT	3-D CRT
Proctitis		
Grade – I	56 %	37 %
Grade – II	15 %	5 %



Clinical applications – Prostate

Clinical data on dose escalation

With 3DCRT - upto 81 Gy

With IMRT - upto 86 Gy

PSA failure free at 3 yrs

>77 Gy 95%

68-77 Gy 70%

<67 Gy 60%

(Pollack et.al, Kupelian et al, Fiveash et al)

MSKCC >81Gy IMRT 81-92%



IMRT in Carcinoma Prostate

Toxicity Profile

Toxicity	Ghadjar P 2008	Coote, JH 2009
1. GIT toxicity		
Grade-II		
Acute	3%	--
Late	8%	4%
Grade-III	None	None
2. GU toxicity		
Grade-II		
Acute	56%	--
Late	28%	4.25%
Grade-III		
Acute	8%	NIL
Late	3%	NIL



Clinical applications – Head & Neck

Oropharynx

Toxicity

Chao et al 2001

Grade II xerostomia

Conventional RT

78-84%

IMRT

17-30%

Eisbruch et al

Severe xerostomia

3DCRT

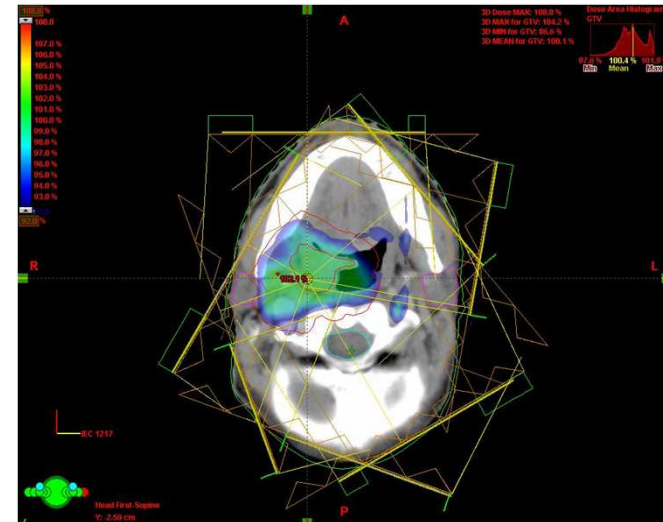
33%

Results

Chao et al 2004

Stages I (2), II (3), III (14), IV (43)

Median FU 33 months - 10 locoregional recurrences





Clinical applications – Head & Neck

Nasopharynx

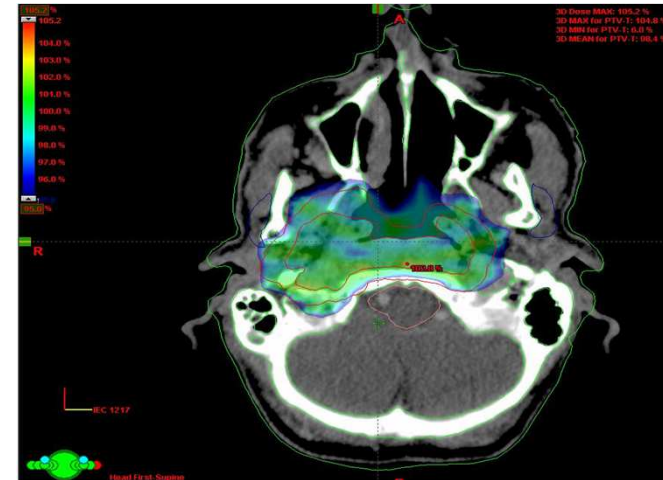
Toxicity

Xia et al 2000

mean parotid dose 21Gy
significant dose reduction to brainstem,
optic chiasm, optic structures.

Results

	LC	OS
UCSF	94%	73%
HongKong	100%	





Results of IMRT in Head & Neck Cancer

Survival Data

Study	No.of pts.	Residual Disease	Local Recurrence	Nodal Recurrence	2 yrs. Overall survival
Studor G 2007		50%	16%	11%	82%
Studor G 2006	71 Post.Op.	--	5%	--	71%
Studor G 2006	115 SIB-IMRT	--	--	--	77%
Thorstad W 2005	356	--	19%	14%	85%
Yao M 2005	151	--	8%	4%	85%
Ghoshal, 2009	20 SIB-IMRT	--	--	--	95%



Results of IMRT Vs. Conventional RT in Head & Neck Cancer

Lee NY , 2006

Comparative Trial

Patients – 112

Disease Control

3 yrs. Survival

CVRT

- 71

85%

IMRT

- 41

95%

Toxicity

Died of toxicity

CVRT

- 3 ,

IMRT

– None

Gastrostomy

CVRT

- 21%,

IMRT

– 4%

Survival

CVRT (3 yrs)

76%

IMRT (3 yrs)

82%



Clinical applications – Other Sites

Breast

improves dose coverage and reduced inhomogeneity

Lung

3DCRT improves dose distribution and reduces dose to normal lung, heart, esophagus and spinal cord. IMRT improves the conformity index compared with 3DCRT. IGRT is being used at various institutions now.

Esophagus

reduces dose to lungs and heart.

Cervix

small bowel dose can be reduced by 50%, and rectal and bladder doses by 23%.



CONFORMAL RADIATION THERAPY

CONCLUSIONS

Conventional treatment is still the best form of radiation therapy for majority of our patients at most of the treatment centers.

Conformal Radiation techniques are available for possible better control and survival of cancer with reduced late radiation morbidity.

However, the patient should be chosen properly who can get required benefits.

Success of conformal techniques depends on meticulous treatment planning.



CONFORMAL RADIATION THERAPY

CONCLUSIONS

These are time consuming and labor intense techniques which may not be feasible for routine practice of radiation therapy in our country for all patients.

Finally the cost involved is prohibitive and therefore, the facility should be established in discrete manner.



CONFORMAL RADIATION THERAPY

“ We have never been near to the old dream of the first Radiotherapist : Irradiating the entire tumour and the only tumour”

“Mauric Tubiana, 2000”



Thank You

