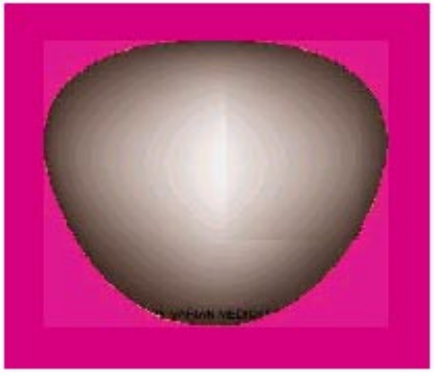
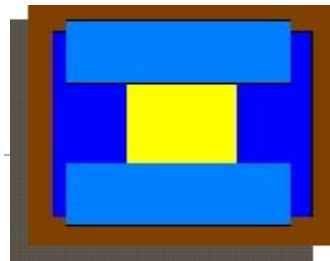
3D Conformal RT: Technical outline and Process

Kazi S Manir



Conventional RT 2D & 3D

- In **conventional** radiotherapy, **simple** field arrangements (single/ opposed beams) are used to **uniformly** radiate both the target and the surrounding normal tissues.
- In **2D** planning, dose distribution is calculated on a **single plane/ contour**, and is possible to do with manually taken contours or simulator images.
- In **3D** planning, dose distribution is calculated at **multiple levels** or throughout the patient volume. 3D planning is not possible without CT/ MRI volume imaging.
- Conventional radiotherapy includes the use of rectangular blocks to shield normal structures.



3-D Conformal Radiotherapy (3-D CRT)

Design and delivery of radiotherapy treatment plans based on 3-D image data with treatment fields individually shaped to treat only the target tissue

IAEA Tech Doc 2008

2D RT

- Based on theoretical anatomy.
- Fields may or may not sufficient to include Microscopic extension.
- Normal tissue irradiation more.
- Based on 2D iso-dose curves.

3D CRT

•Based on practical approach to a particular anatomy.

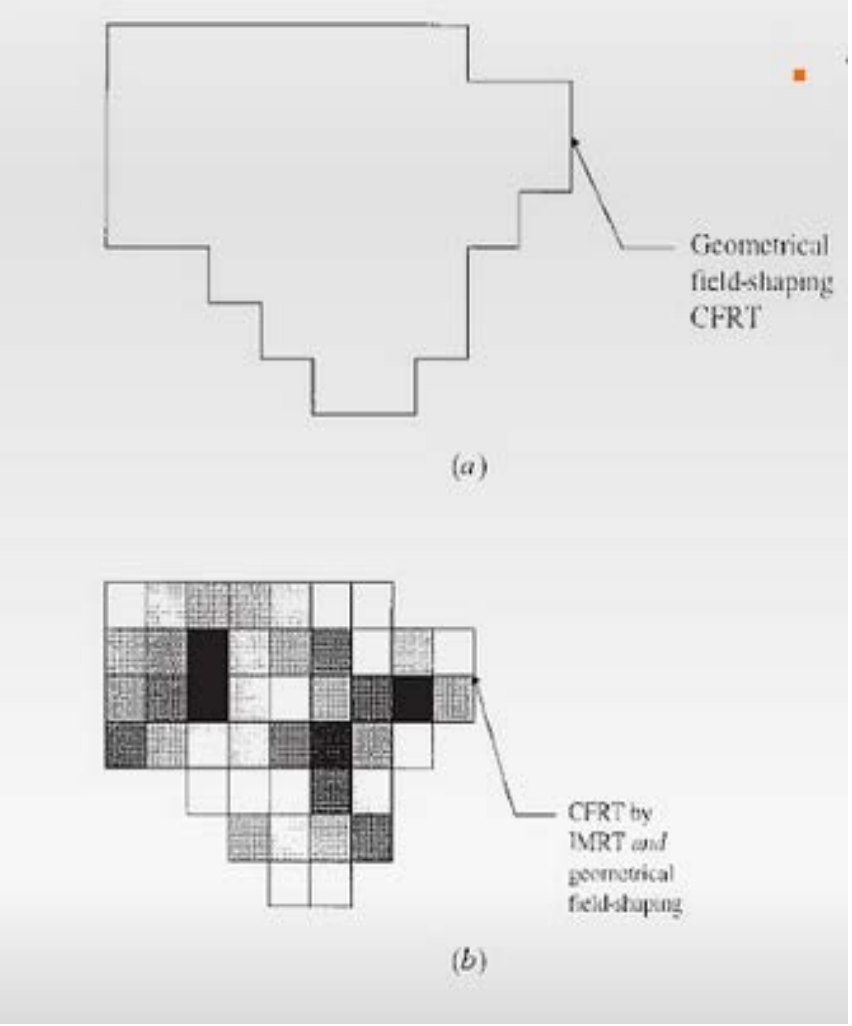
•Fields are based on actual size of the tumor.

•Lesser normal tissue irradiation

•3D Iso-dose curves can be obtained`

- **Better spatial localization of high dose irradiated volumes**

Types of 3-DCRT

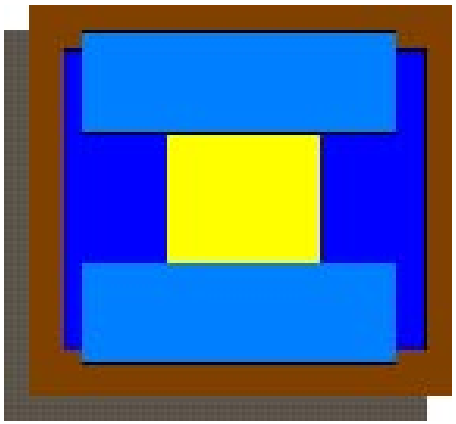


- 3D-CRT:
- Geometric field shaping alone

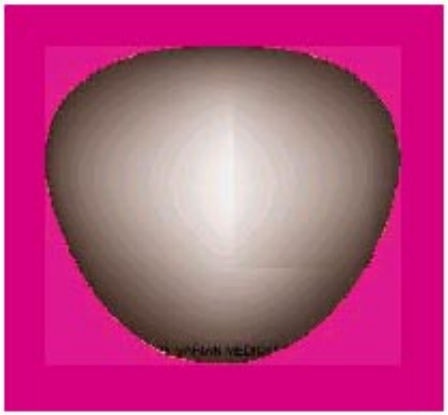
- IMRT:
- Modulation of intensities across the geometrically shaped field

Evolution of Treatment Techniques

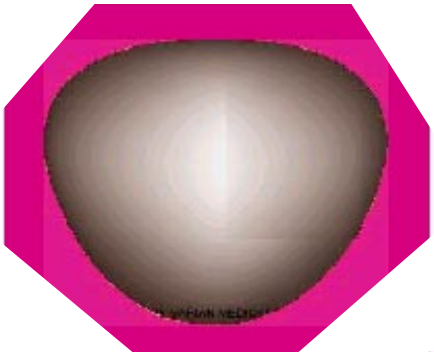
CONVENTIONAL RT



Collimator shapes Beam



Rectangular Treatment Field

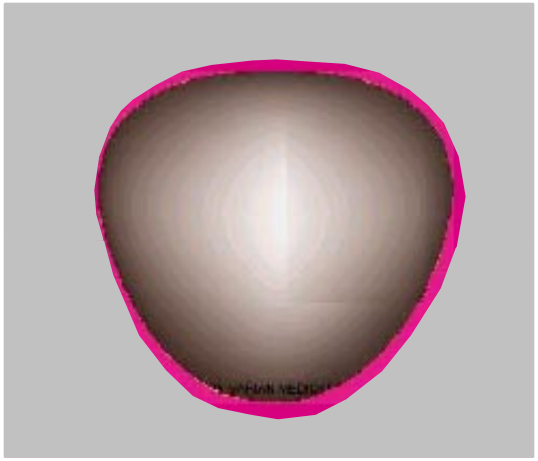


Shaped Treatment Field

1970s and earlier

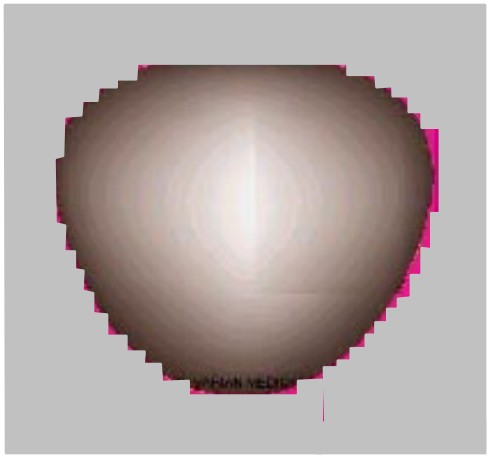
Evolution of Treatment Techniques

CUSTOMISED BLOCKS



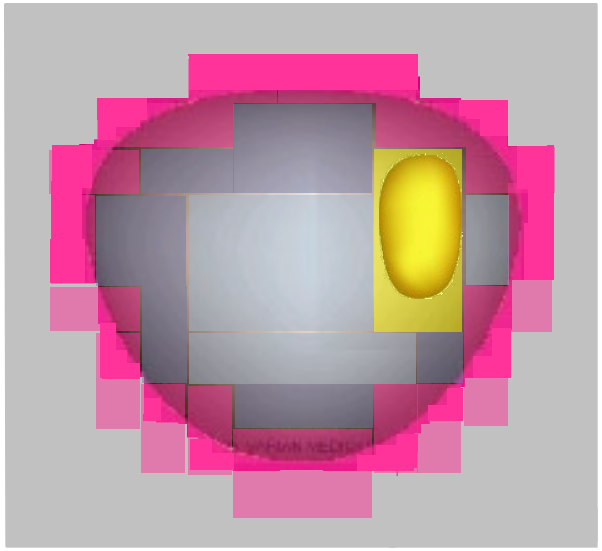
1980s

MULTILEAF COLLIMATOR BASED 3D-CRT



1990s

IMRT

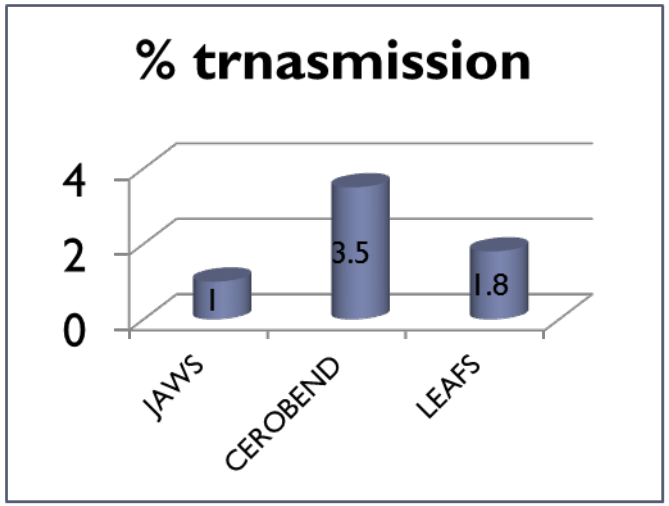


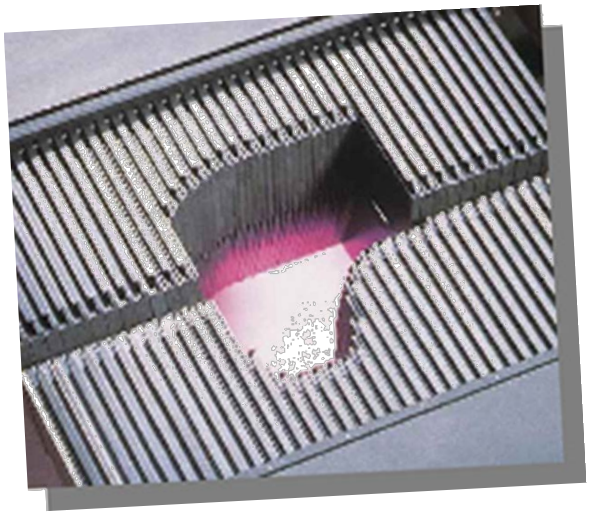
IMRT
Initiated in 1995
Reached the clinic in 2000

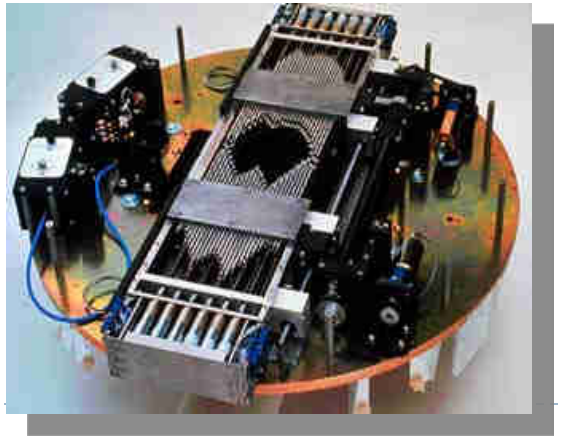
- Divides each treatment field into multiple segments
- Modulates beam intensity, giving discrete dose to each segment
- Uses multiple, shaped beams (~9) and thousands of segments
- Uses Inverse Planning software

Multi Leaf Collimator

- large number of collimating blocks or leaves that can be driven automatically, independent of each other, to generate a field of any shape
- Primary beam transmission:





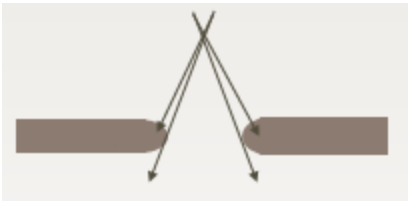


Why MLC?
Modulated therapy (VMAT/IMRT)
3D conformity

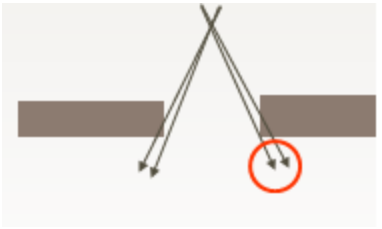
MLC : general features

- ≥**40** pairs of leaves having a width of ≤ **1 cm** (projected at the isocenter).
- Latest Varian has 60 pairs
- Thickness = **6 – 7.5 cm (** E dependent)
- Made of a tungsten alloy.
- Density of **17 - 18.5 g/cm^3**.
- Primary x-ray transmission:
  - Through the leaves < **2%.**
  - Interleaf transmission < **3%**
  - **types:**
  - Double focus
  - Single focus(Non focus) Varian, Electa

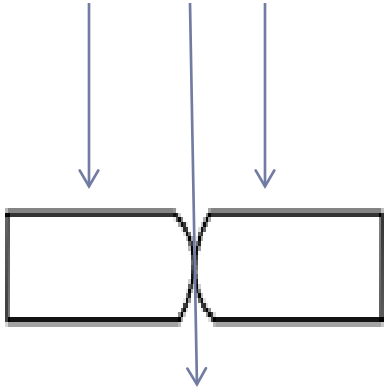
Significant beam (20%) transmission when rounded leafs are abutted



Single Focus



Double Focus



MLC

- In order to allow …hile reducing radiation transmis… **ve design** is often used.
- This design in tur… **osing** in the region of the tongue (17…

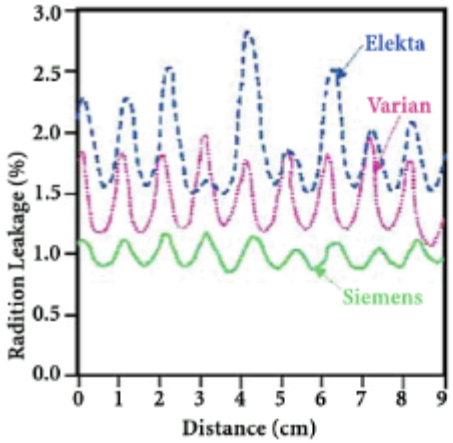
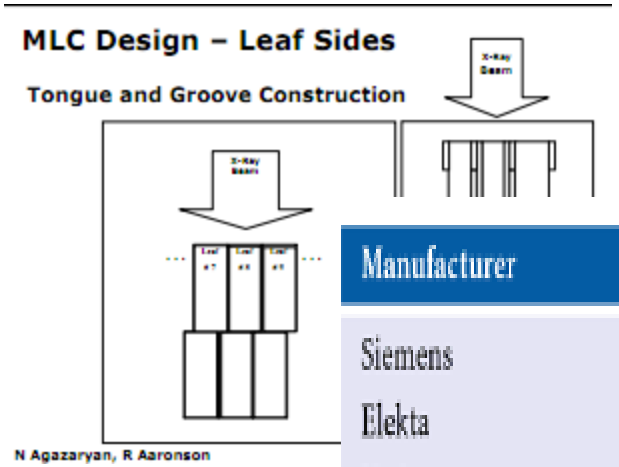
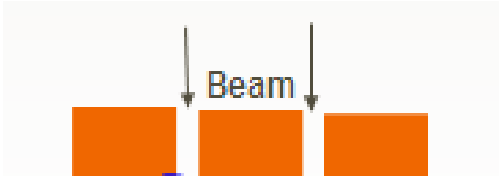


Fig. 1. Leakage patterns for the major MLC collimators. From: Huq MS, Das IJ, Steinberg T, Galvin JM (2002) A dosimetric comparison of various multileaf collimators. Phys Med Biol 47(12):N159–N170. Reprinted with permission





Manufacturer	Inter-leaf (%)	Intra-leaf (%)	Leaf-end (%)
Siemens	1.1	0.8	1.6
Elekta	2.5	1.6	> 20%
Varian	1.8	1.2	> 20%

MLC design

1.Upper Jaw replacement

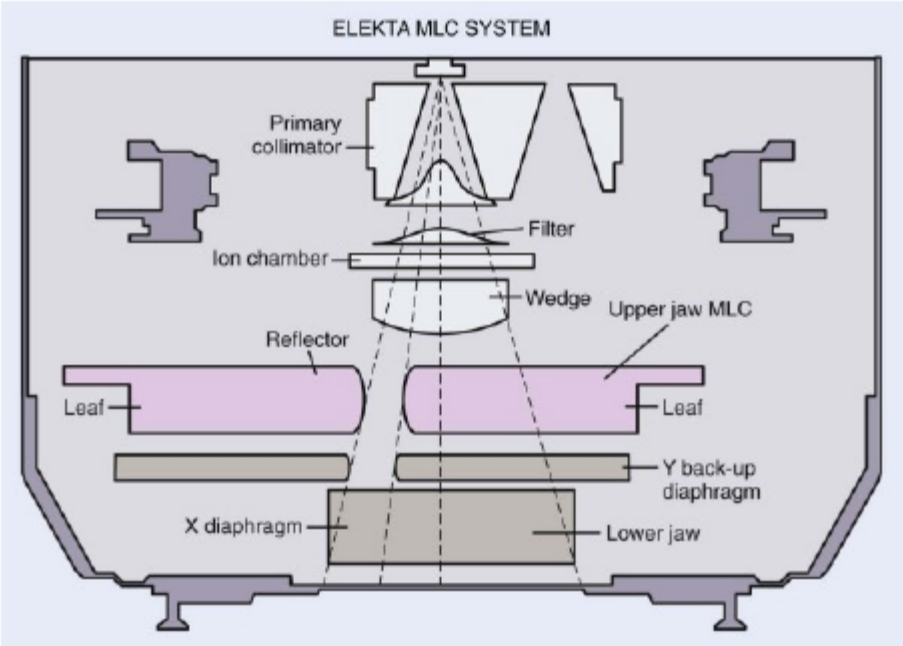


FIGURE 10-12 • A schematic drawing of the Elekta multileaf collimator.
(From Van Vvk J [ed]: The modern technology of radiation oncology, Madison, WI, 1999, Medical Physics

MLC

2.Lower Jaw Replacement

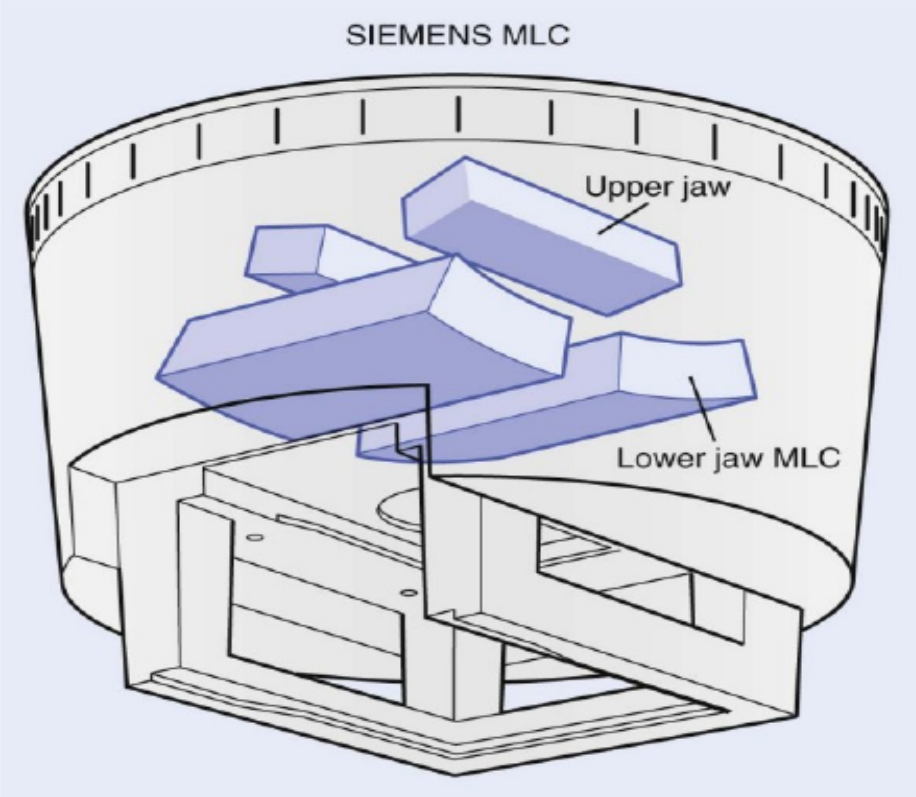


FIGURE 10-13 • A schematic drawing of the Siemens multileaf collimator.
(From Van Vyk J [ed]: The modern technology of radiation oncology, Madison, WI, 1999, Medical Physics Publishing.)

MLC

3. Tertiary MLC:

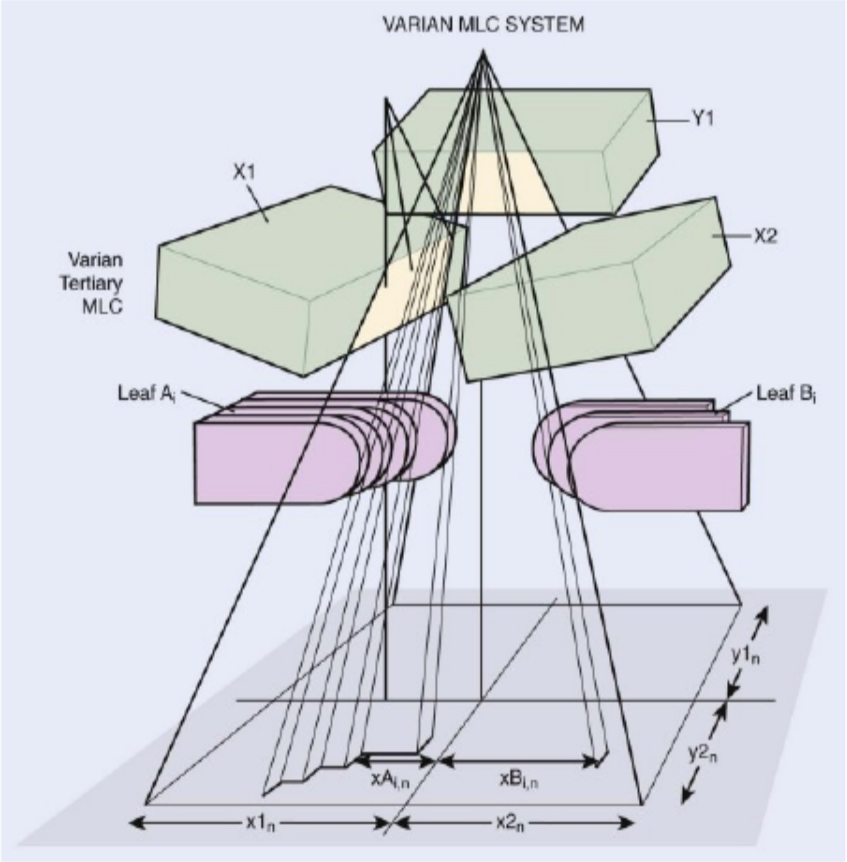


FIGURE 10-14 • A schematic drawing of the Varian multileaf collimator.
(From Van Vyk J [ed]: The modern technology of radiation oncology, Madison, WI, 1999, Medical Physics Publishing.)

Specifications commercial MLCs used in 3DCRT and IMRT solutions

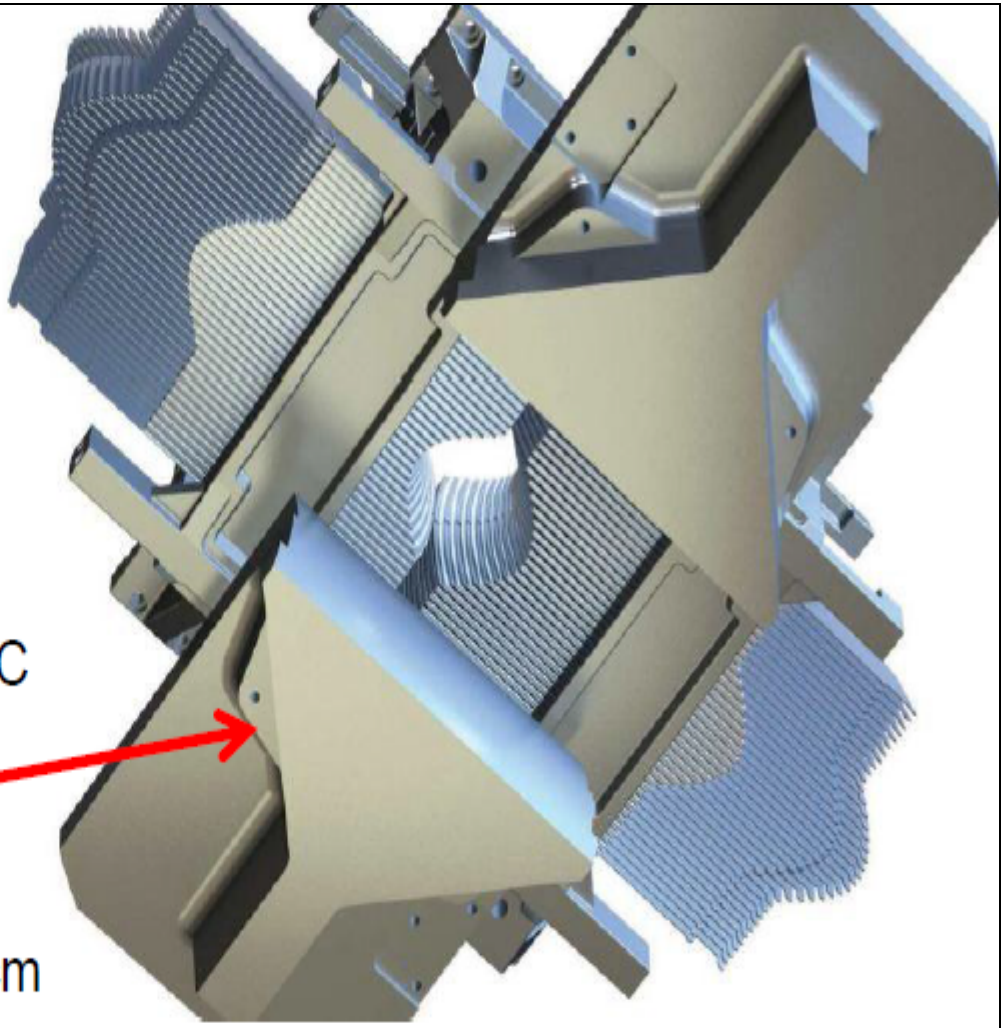
ELECTA MLCi

- Number of Leaf Pairs: 40
- Field Size: 40 cm x 40 cm
- Leaf Width at Isocenter: 1 cm
- Maximum Overtravel: 12.5 cm
- Leaf Transmission: < 3%
- Maximum Leaf Speed: 2 cm/sec
- Clearance to Isocenter: 45 cm
- Replaces Upper Jaw Pair (+ Backup Jaws)

- Lower jaw only to central axis

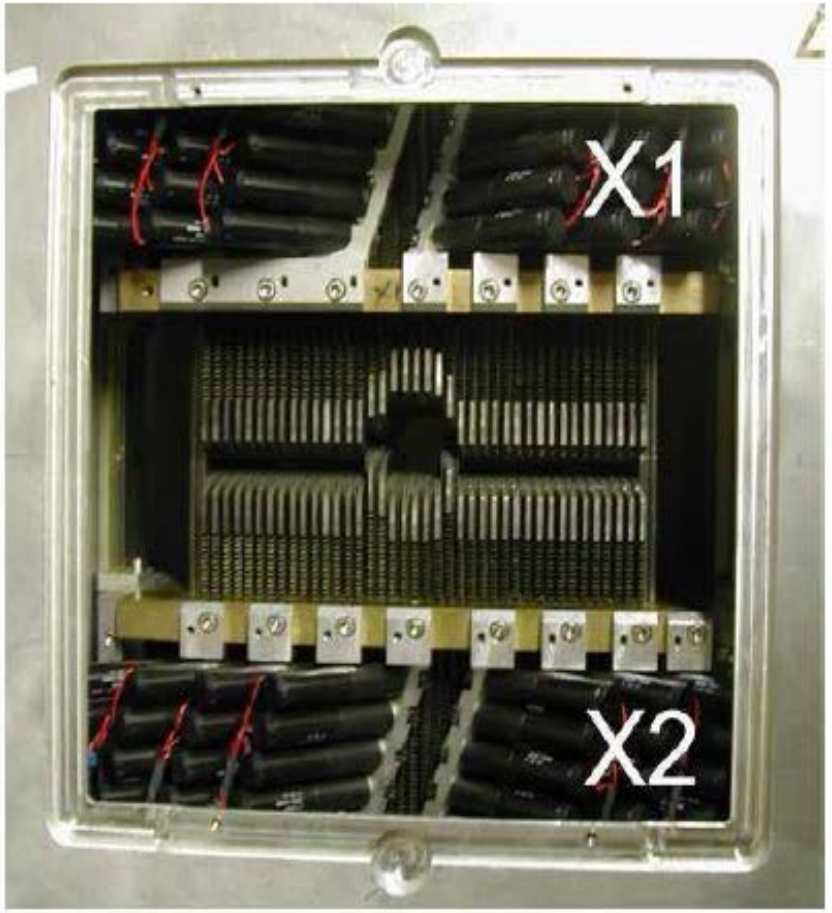
MLC 160, ELECTA Agility

- # of leaf pairs: 80
- Max. field size: 40x40 cm^2
- Leaf width : 5 mm
- Max. Overtravel: 15 cm
- Leaf Transmission: <1%
- Maximum Leaf Speed: ~ 6 cm/s
- Replace upper jaws
- 20cm max difference of MLC leave on one bank
- "Lighter" lower jaws
- Jaws overtravel by 12cm
- Clearance to Isocenter: 45cm



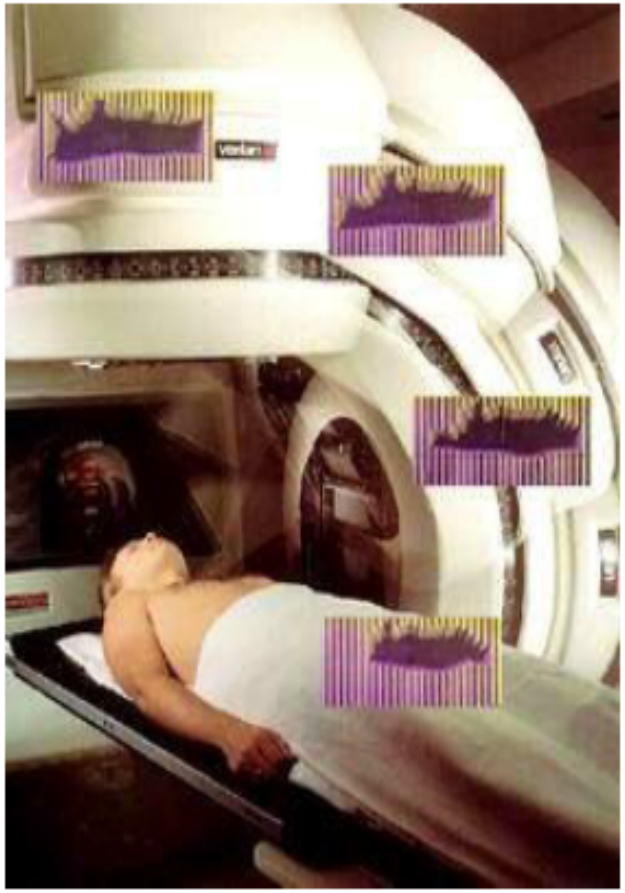
Siemens MLC 160

- Number of Leaf Pairs: 80
- Field Size: 40 cm x 40 cm
- Maximum Overtravel: 20 cm*
- Leaf Width at Isocenter: 0.5 cm
- Leaf Transmission: <1%
- Maximum Leaf Speed: > 4 cm/s
- Clearance to Isocenter: 43 cm
- Single-Focused Design
- Replaces Lower Jaw Pair



Varian MLC

- Number of Leaf Pairs: 26 or 40 or 60
- Field Size: 40 cm x 26 cm
  or 40 cm x 40 cm
- Maximum Overtravel: 16 cm
- Maximum Leaf Separation: 14.5 cm
- Leaf Width at Isocenter: 0.5cm
  or 1cm
- Leaf Transmission: < 4%
- Maximum Leaf Speed: 1.5 cm/sec
- Clearance to Isocenter: 41.5 cm



MLC design

The physical leaf length (project at isocenter) differ between vendors.

- Varian: 16 cm
- Siemens: 30 cm
- Elekta: 32.5 cm (MLCi)
  20 cm (Agility)

The distance that each leaf passes over the isocenter is called over-travel distance, without leaving an uncovered region.

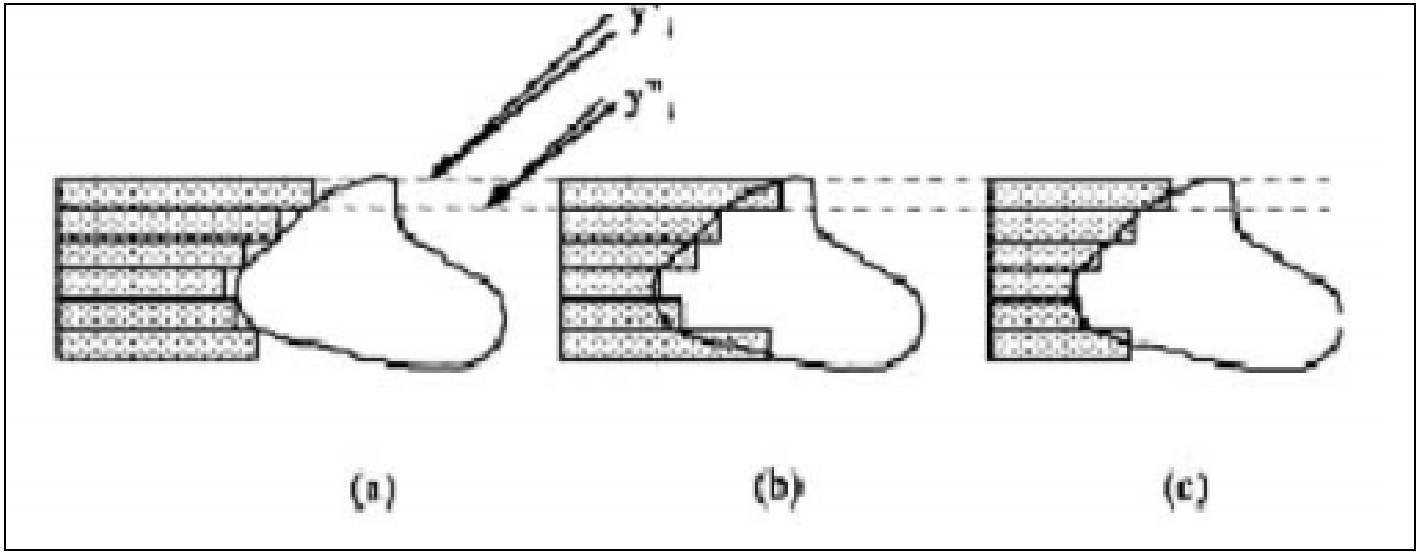
- Varian: 17 cm (34 x 26 cm2)
- Siemens: 10 cm (21 x 29 cm2)
- Elekta: 12.5 cm (25 x 40 cm2) MLCi
  15 cm (30x 40cm2) Agility

MLC positions in 3D CRT

Leaf coverage strategies in relation to PTV

a) Out of Field of Strategy
b) In Field strategy
c) Cross boundary strategy

Cross boundary strategy: Most widely used clinically



Jeraj M et.al. Radiol Oncol 2004

Problems of 3DCRT

1. Expensive:
2. Machine, Imaging, Hardware, Software
3. Expert Manpower
4. Labor intensive time consuming
5. Precise: so chance of setup error ,motion problem
6. Organ delineation variability

Process of 3DCRT planning

1. Positioning and Immobilization
2. Imaging, Image transfer , registration (and fusion)
3. Image segmentation (Volume delineation)
4. Treatment planning
5. Plan evaluation and improvement
6. Plan Implementation and treatment verification (set up)
7. Treatment Delivery
8. Quality Assurance

Steps of 3DCRT:Head Neck Cancer

I. Positioning and immobilization

Ideal Immobilization device: FAQ

- Is the patient fully supported in a comfortable and relaxed position?
- Does the device provide a tactile reminder to the patient of how it feels when the setup is consistent with previous treatment?
- Is the patie
- Does the d rs?
- Is the devic der treatment?
- Can the de ize normal tiss
- Does the d ms?
- Will the de MRI, or other treatment planning imaging systems?
- Will the surface dose be adversely affected?
- Does the device provide adequate space for reference marks to fully describe and facilitate reproducibility of the patient setup?
- Will the immobilization device be rigid and hold its shape over time?

Cheap and easy to use

- **Positioning device Vs Immobilization device: Similar?**

Positioning devices are ancillary devices used to help maintain the patient in a nonstandard treatment position

Special position designed to improve the therapeutic ratio

Types of Devices:

Indexed

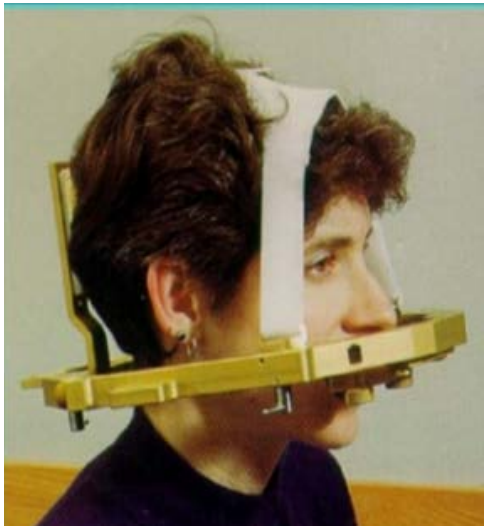
Non Indexed

Frameless

Frame based 

Invasive
Non Invasive

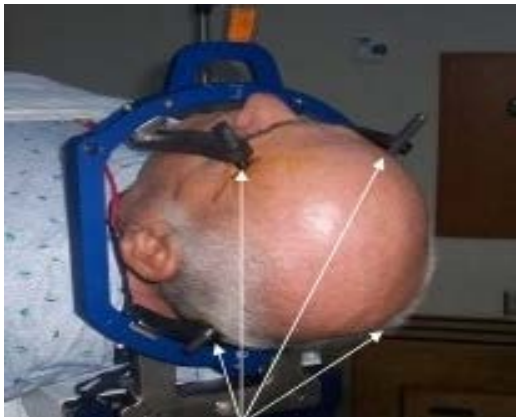
Cranial Immobilization



Gill Thomas
Cosman System

TLC System

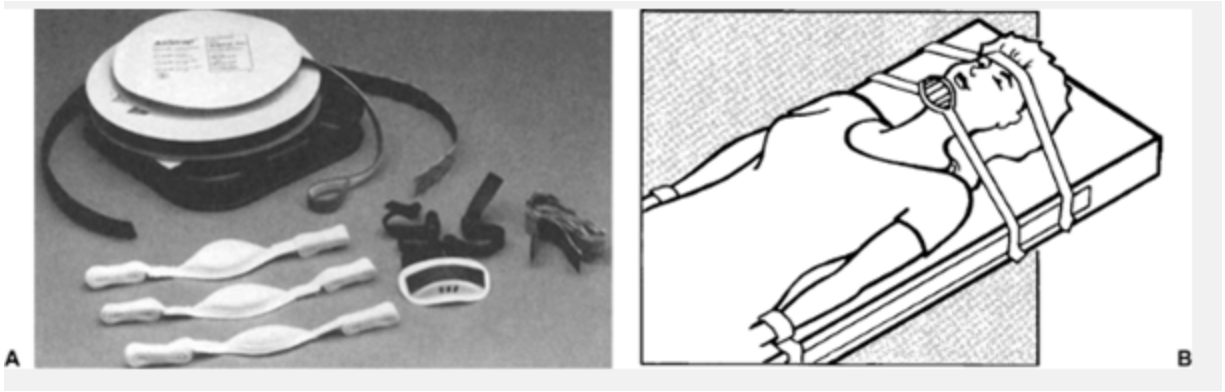
Leksell System



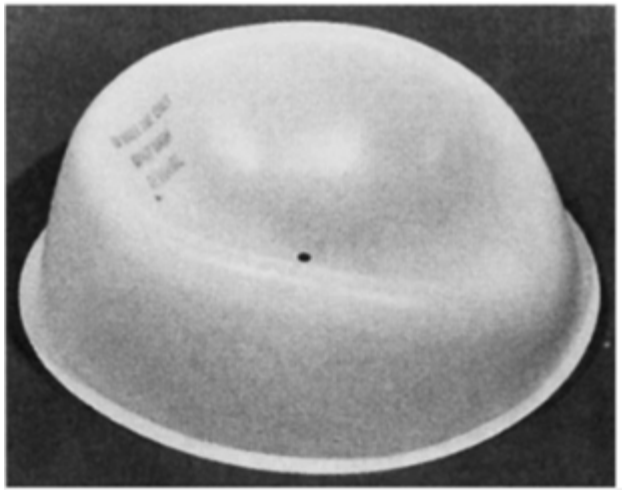
Brain Lab Frame

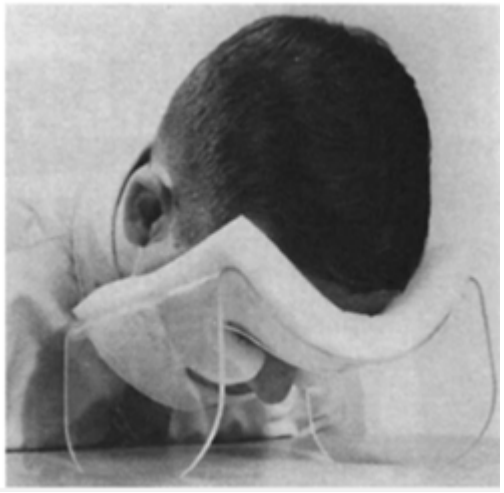
Head Neck Immobilization

- **Velcro restraining straps**



- Generic Plastic Head holder

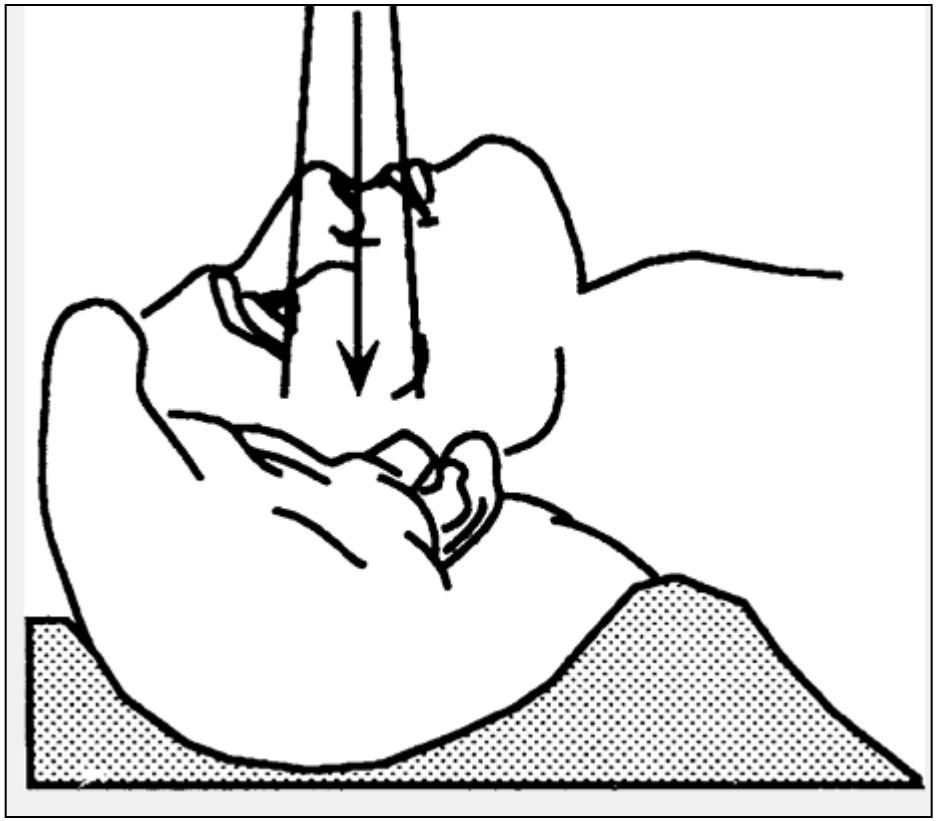




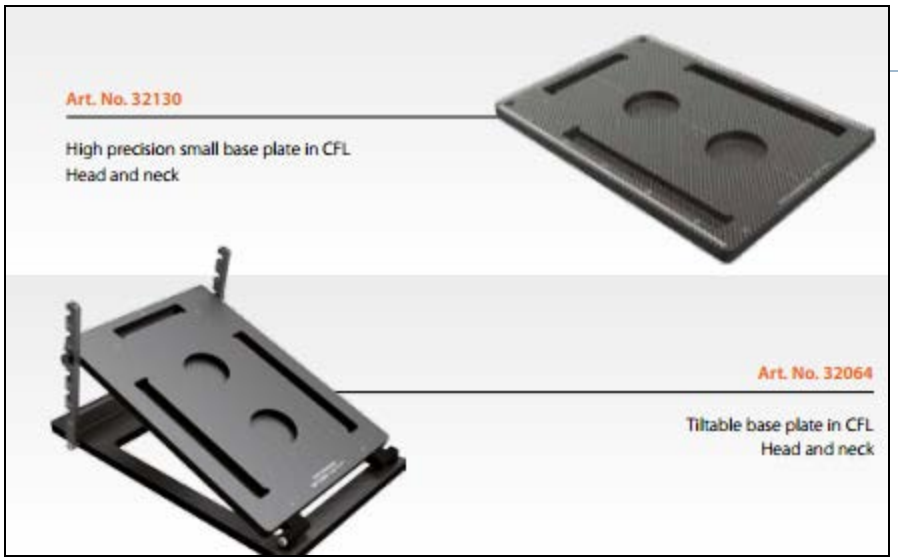
Formed Plastic face down stabilizer

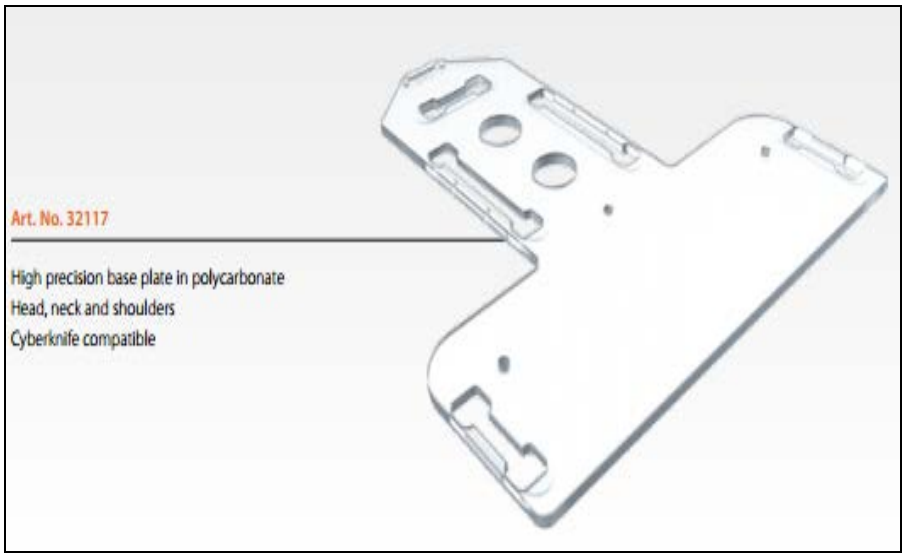
Timo Head Rest: Indexed
(Colour coded/Letter coded)

Why extended ???

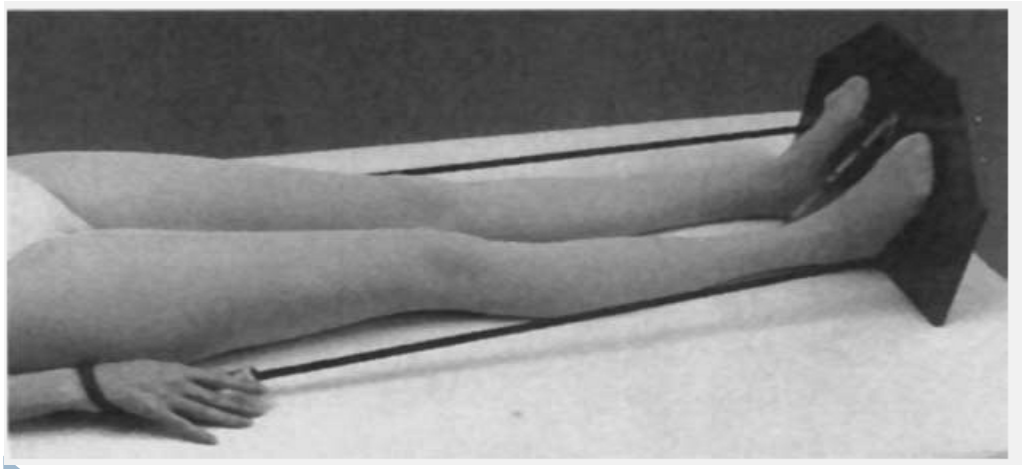


Head Neck Base Plate



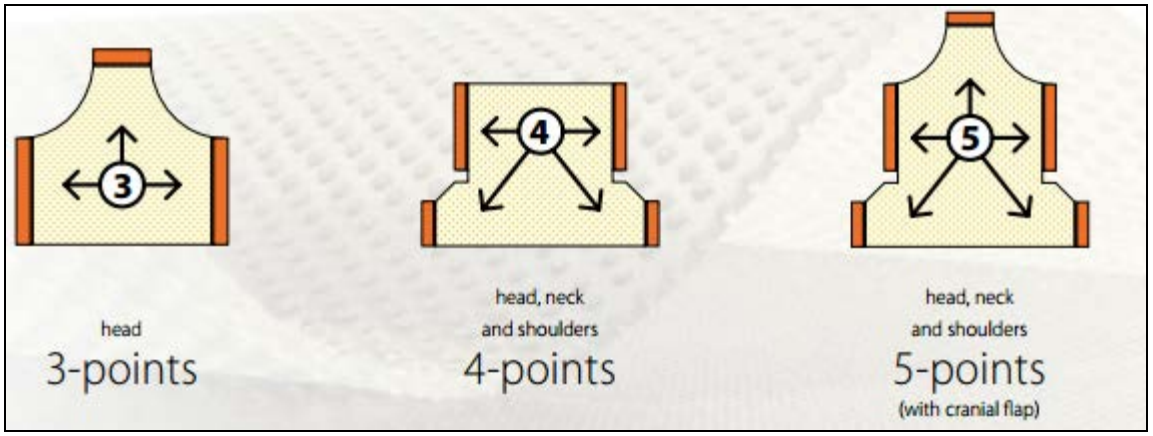


Shoulder Retractor



Thermoplastic immobilization device

- Low-temperature orthopaedic plastics



Guidelines for patient positioning in head and neck cancer

Setup the patient with neutral neck position.

minimizes intra-fraction patient motion

Use a customized head and neck support and face mask for each patient.

improves accuracy of field matching (Neck and LAN fields)

Index immobilization apparatus to the treatment table.

Improves treatment setup efficiency and accuracy

Use active patient position monitoring system (LED camera System)

Improves setup accuracy and reproducibility, and minimizes intra-fraction patient motion

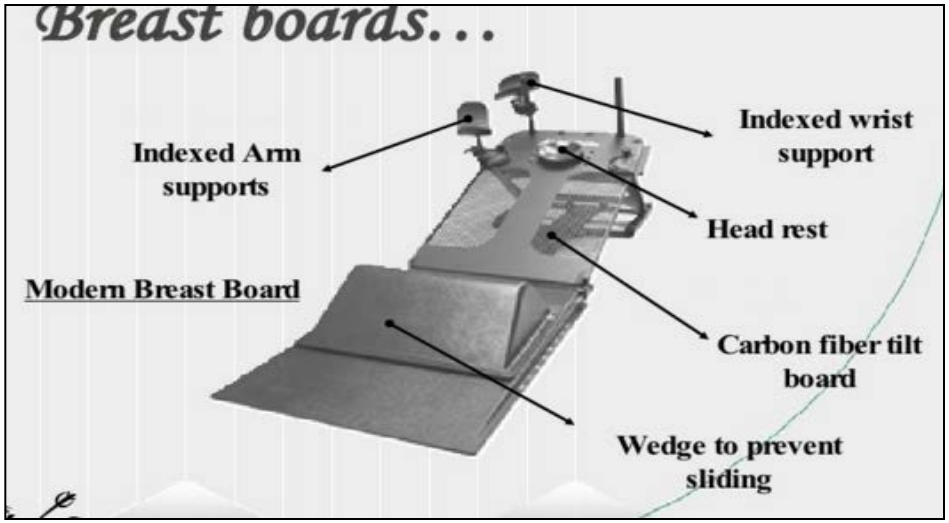
These strategies can reduce the setup random errors to less than 2 mm for upper neck.

J P Agarwal TMH ESTRO EBM 2005

Thorax and Breast Immobilisation

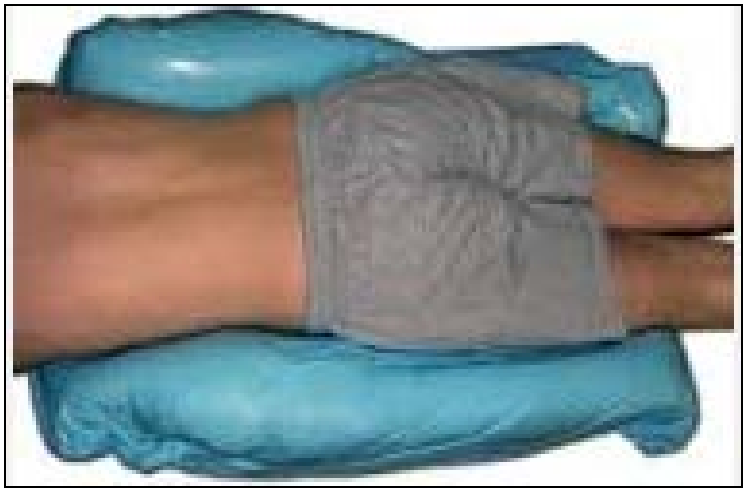
Vac Lok

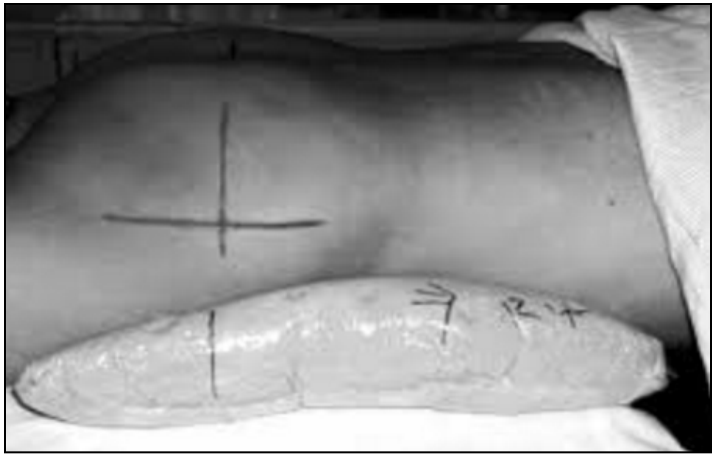
Prone Breast Board



Pelvic Immobilization

Pelvic board and Positioning with thermoplastic device





2.a. Imaging

- 70 – 85 cm bore
- Scanning Field of View (SFOV) 48 cm – 60 cm – Allows wider separation to be imaged.
- Multi slice capacity:
  - Speed up acquistion times
  - Reduce motion and breathing artifacts
  - Allow thinner slices to be taken – better DRR and CT resolution
- Allows gating capabilities
- Flat couch top – simulate treatment table

Use of CT SCAN

- The CT information is useful in two aspects of treatment planning:
- Delineation of target volume and the surrounding structures in relation to the external contour
- Providing quantitative data (in the form of CT numbers) for tissue heterogeneity corrections.

- *Magnetic Resonance Imaging*

Magnetic Resonance Imaging

- Magnetic resonance imaging (MRI), nuclear magnetic resonance imaging (NMRI), or magnetic resonance tomography (MRT) is a medical imaging technique to visualize detailed internal structures.

- MRI makes use of the property of nuclear magnetic resonance to image nuclei of atoms inside the body

Magnetic Resonance Imaging

- Advantages over CT Scan:-

- Can be used to scan directly in axial, sagittal, coronal, or oblique planes. This makes it possible to obtain optimal views to enhance target delineation.
- Does not involve the use of ionizing radiation
- Higher contrast, and better imaging of soft tissue tumors.

Magnetic Resonance Imaging

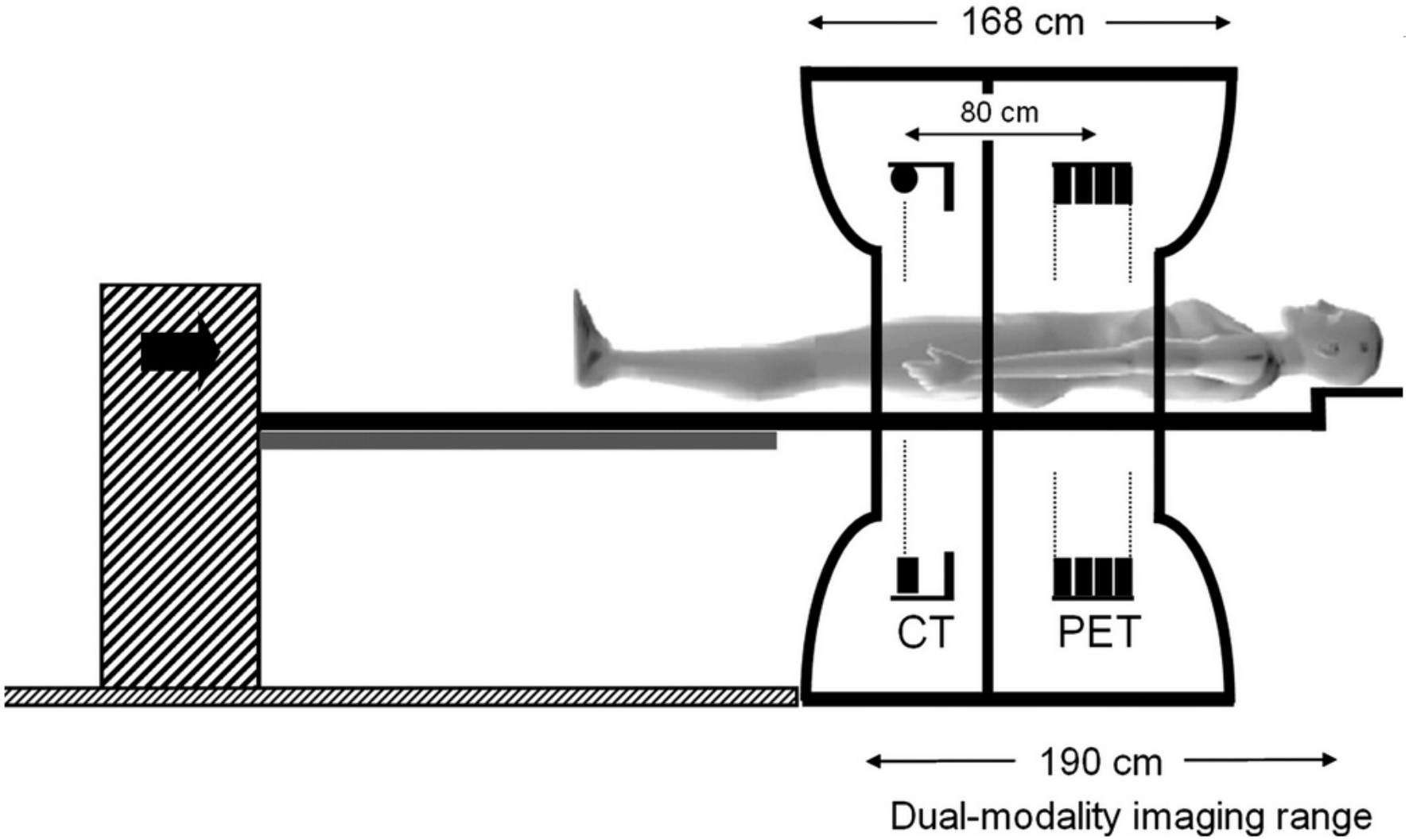
- Disadvantages of MRI:-

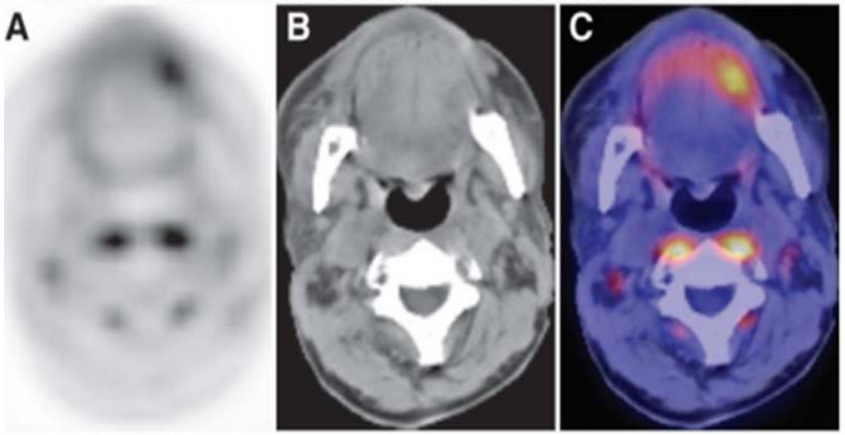
- Lower spatial resolution
- Inability to image bone or calcifications
- Longer scan acquisition time - motion artifacts
- Technical difficulties due to small hole of the magnet
- Magnetic interference with metallic objects.

Emission Tomography

- SPECT
- PET CT

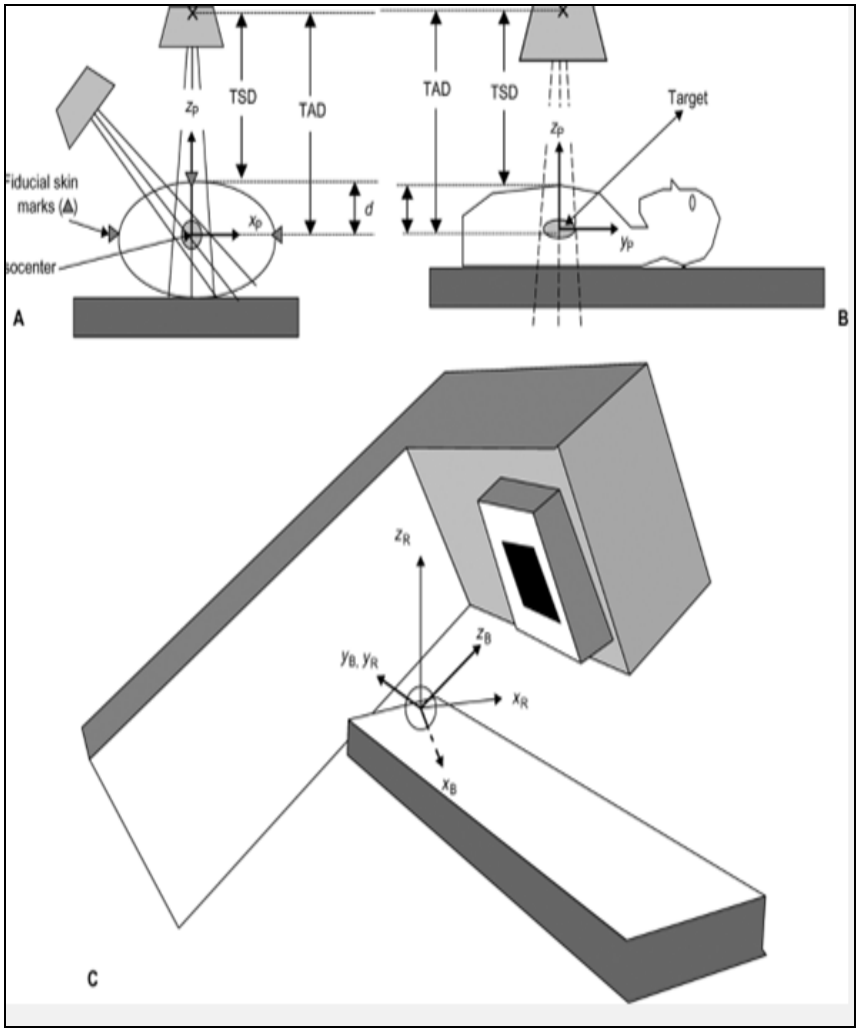
PET-CT





Transaxial images in a 64-year-old man with tongue cancer; status after chemotherapy and radiation therapy. Clinical examination revealed no evidence of disease. *A*, FDG PET scan demonstrates hypermetabolic focus in the left oral cavity. *B*, Nonenhanced CT scan does not show clear abnormality. *C*, PET/CT fused image shows abnormal FDG uptake on the left side of tongue. Biopsy results helped confirm recurrent carcinoma.

- **Metabolic marker**
  - 2- ^{18}Fluoro 2- Deoxy Glucose
- **Proliferation markers**
  - Radiolabelled thymidine: ^{18}F Fluorothymidine
  - Radiolabelled amino acids: ^{11}C Methyl methionine, ^{11}C Tyrosine
- **Hypoxia markers**
  - ^{60}Cu-diacetyl-bis(N-4-methylthiosemicarbazone) (^{60}Cu-ATSM)
- **Apoptosis markers**
  - $^{99}_{m}$Technicium Annexin V



Co-ordinate System:

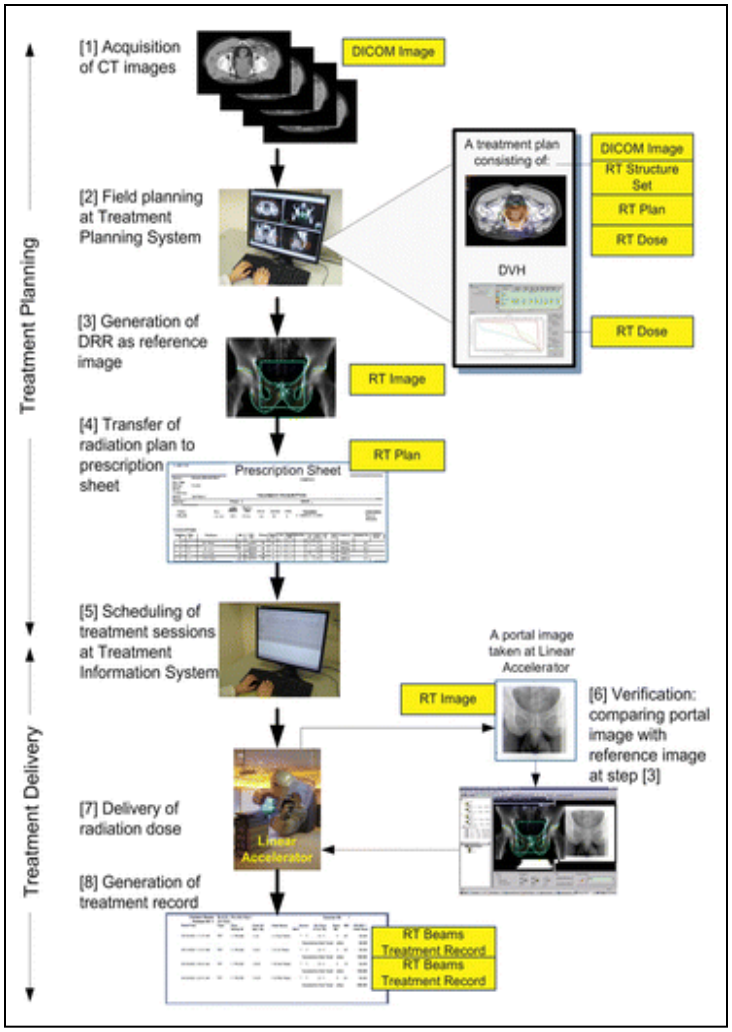
X-axis	Y-axis	Z-axis
Horizontal axis of transverse CT images. (Left: +ve)	Along vertical axis. (Ant : -- ve)	Along the couch motion. (Upward: --ve)

NB: In treatment position.

2.b. Image Transfer

- Picture Archiving and Communication system (PACS)
- Commonly used

Digital Imaging and Communication in Medicine (DICOM-RT)



2.c.Image registration and fusion

Geometric (& Photometric) alignment of one image with another

Key steps:

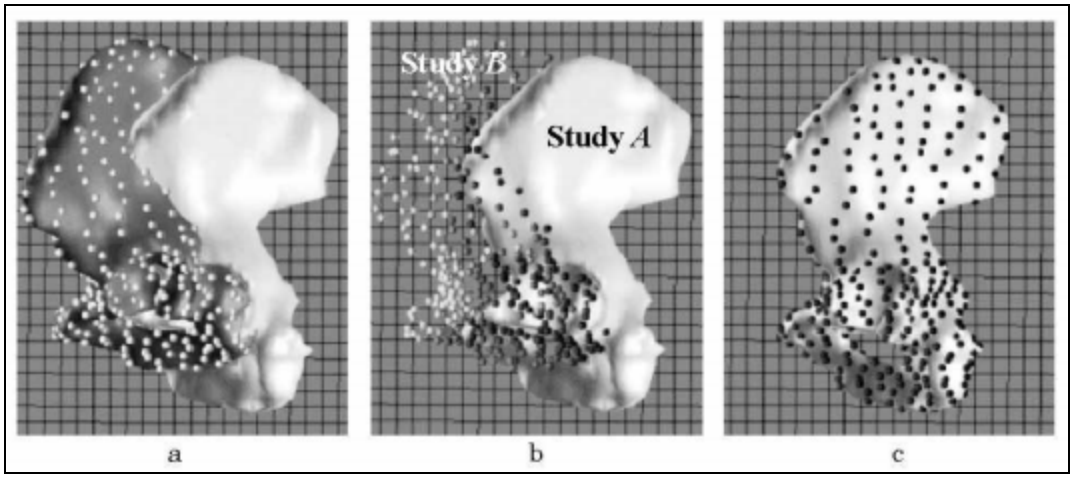
1. Data Registration
2. Structural Mapping and Image Fusion

Data registration

Estimate the parameters of the coordinate transformation that relates homologous points in the two studies.

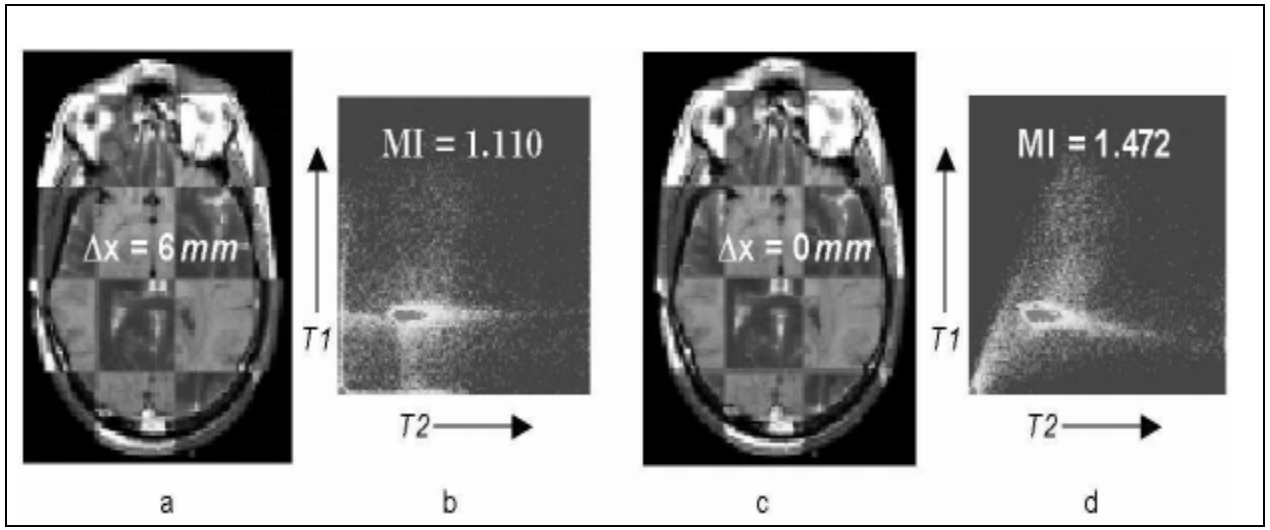
Types:

1. **Surfaced-based Registration**



AAPM 2001

2.Image based registration



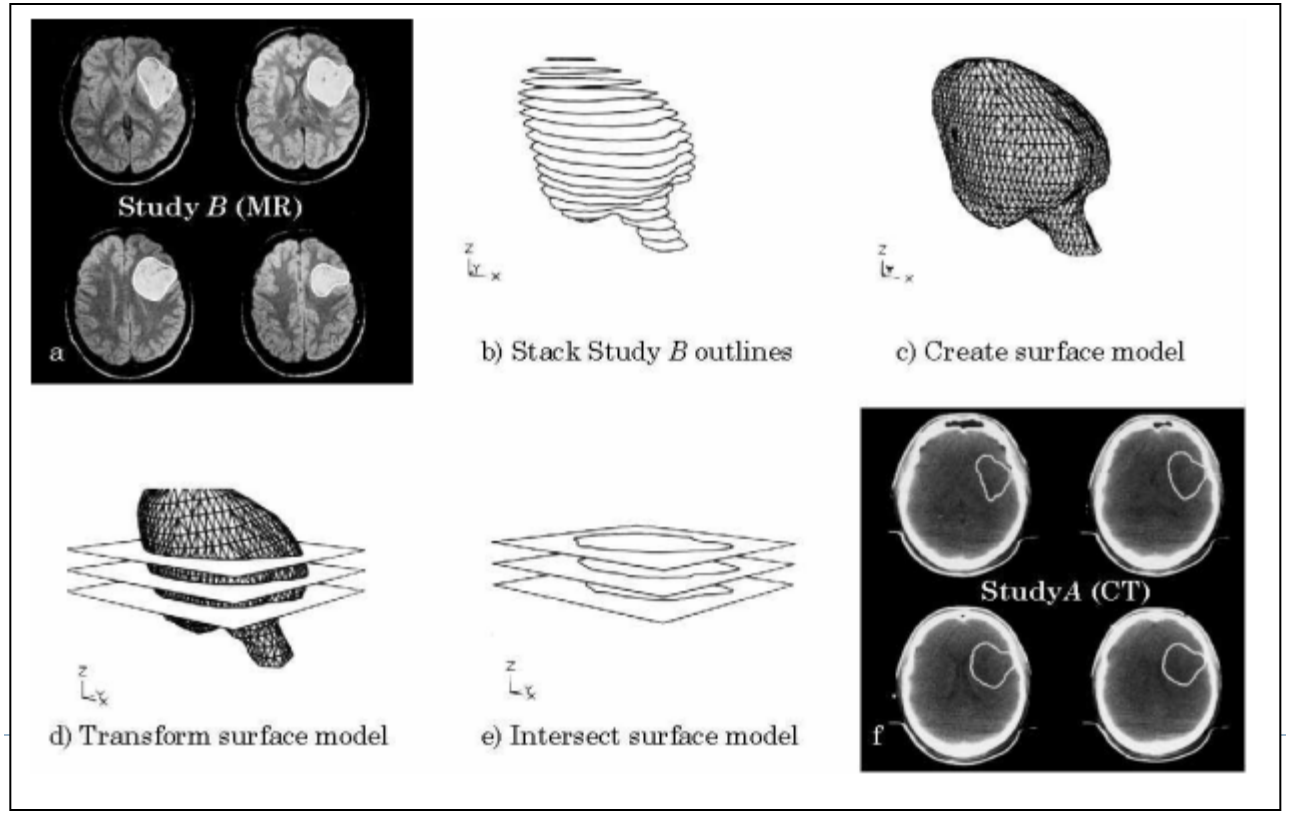
AAPM 2001

Structural mapping & Image Fusion

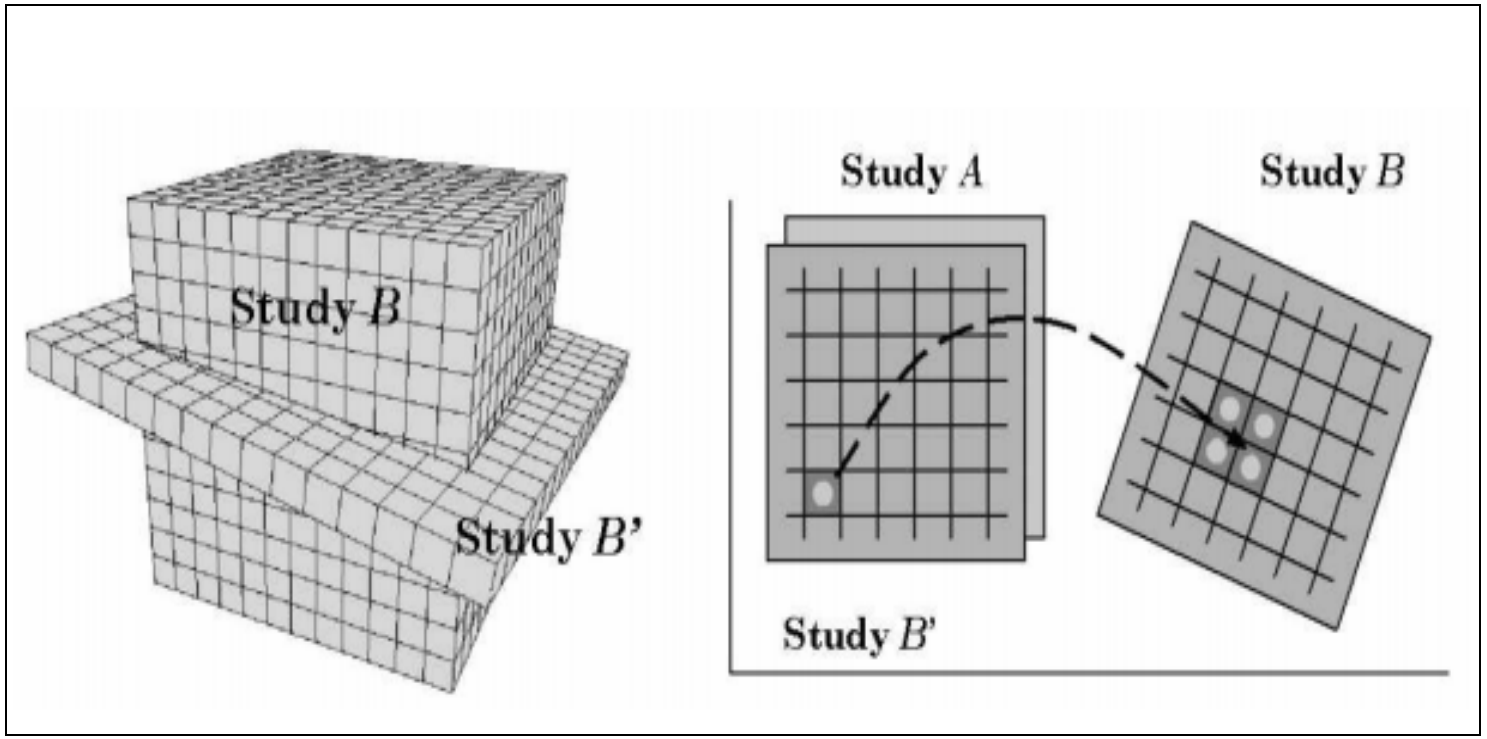
- **Structural Mapping**

Maps the outlines of anatomic structures or treatment volumes defined from one imaging study to the other.

Process 1:

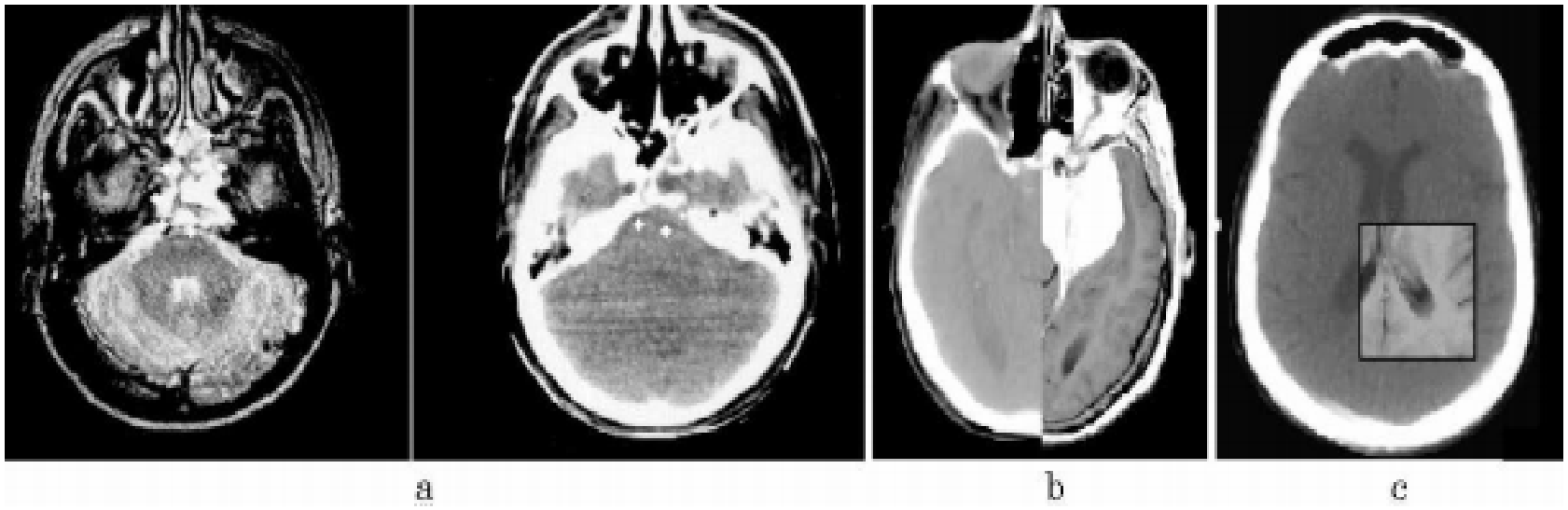


- Structural Mapping
- Process 2:



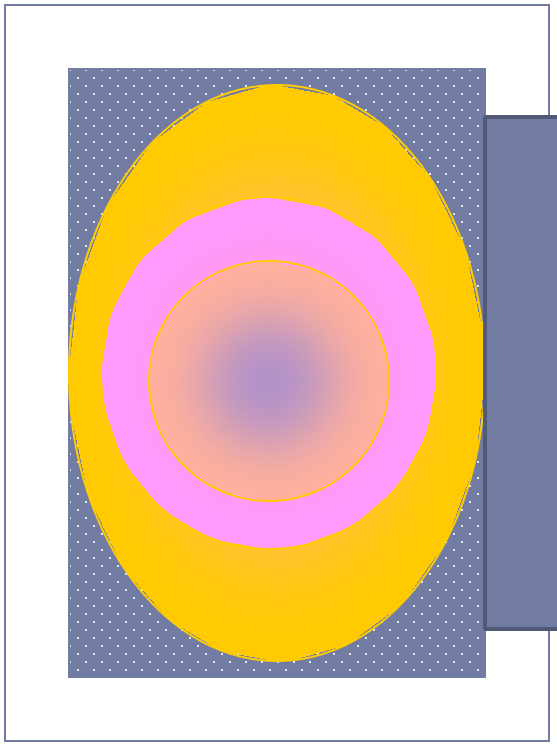
Fused Image Display:

- Electronic Pantograph (a)
- Split Screen Display (b)
- Movable sub window (c)



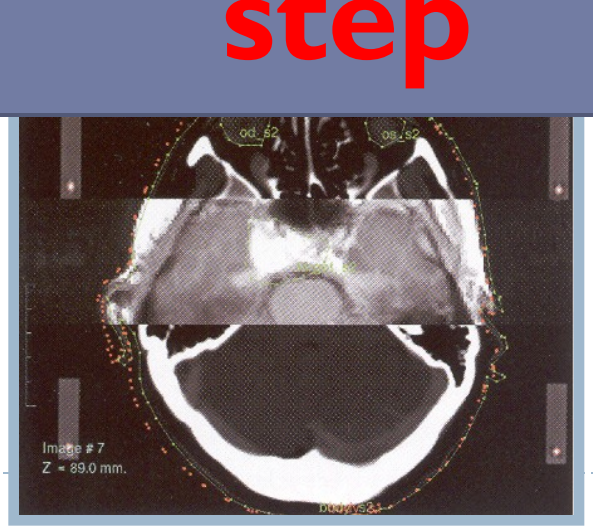
3. Delineation of volumes: Image segmentation

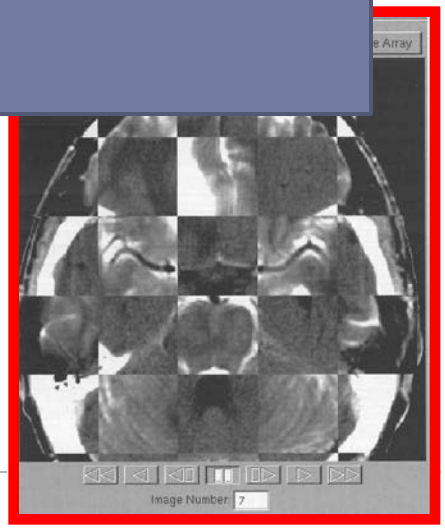
3. Delineation of volumes: Image segmentation



- **should be done by experienced radiation oncologists taking**

Most Important and error prone step

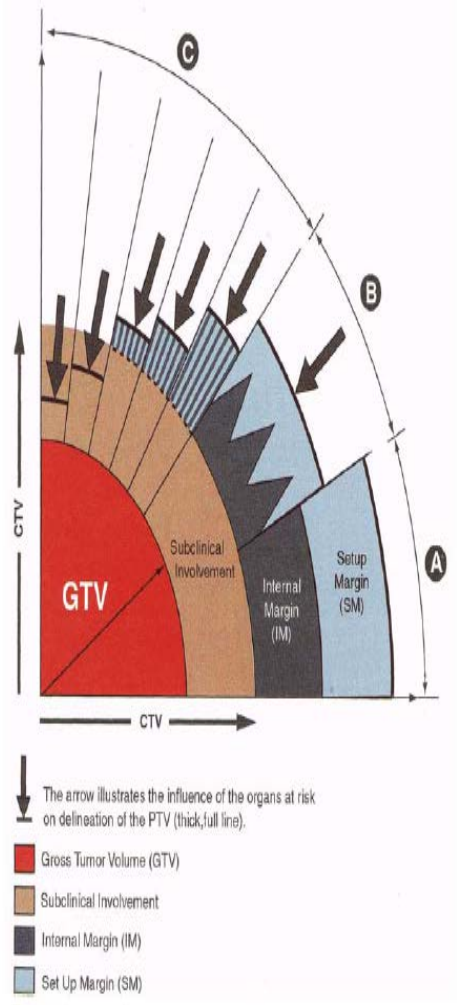




ICRU 50 and 62

- **GTV**: Macroscopic extent of the tumor as defined by radiological and clinical investigations.
- **CTV**: The GTV together with the surrounding microscopic extension of the tumor constitutes the CTV. The CTV also includes the tumor bed of a R0 resection (no residual).
- **ITV (ICRU 62)**: The ITV encompasses the GTV/CTV with an additional margin to account for physiological movement of the tumor or organs. It is defined with respect to a internal reference – most commonly rigid bony skeleton.
- **PTV**: A margin given to above to account for uncertainities in patient setup and beam adjustment.

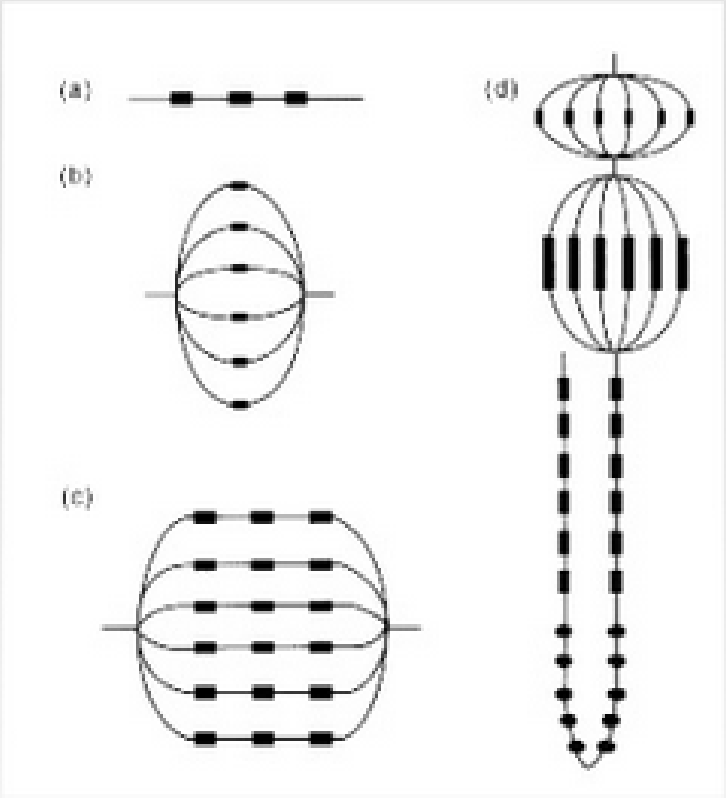
ICRU 50 and 62



Treated Volume: Volume of the tumor and surrounding normal tissue that is included in the isodose surface representing the irradiation dose proposed for the treatment (V_{95})

Irradiated Volume: Volume included in an isodose surface with a possible biological impact on the normal tissue encompassed in this volume. Choice of isodose depends on the biological end point in mind.

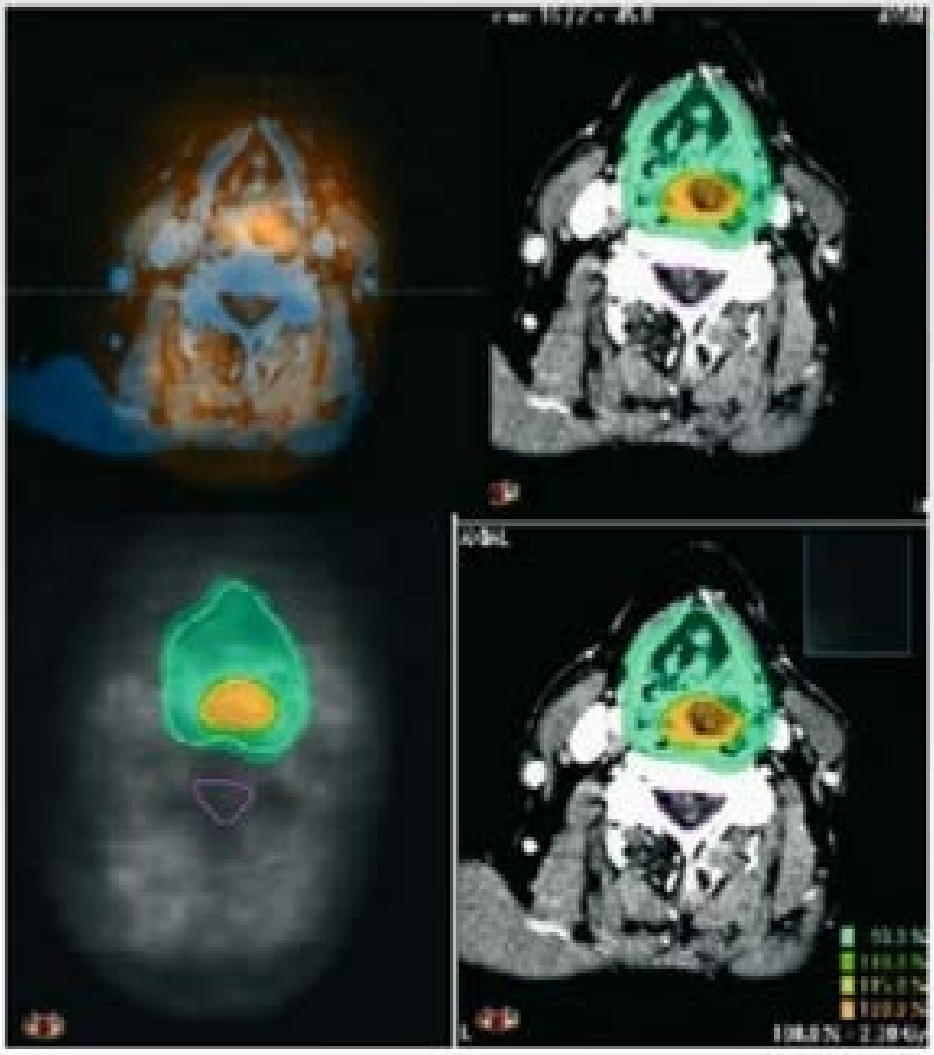
ICRU 62



- Normal critical structures whose radiation sensitivity may **significantly** influence treatment planning and/or prescribed dose.
- A planning organ at risk volume (**PORV**) is added to the contoured organs at risk to account for the same uncertainities in patient setup and treatment as well as organ motion that are used in the delineation of the PTV.
- Each organ is made up of a functional subunit (**FSU**)

ICRU Report 29 (1976-1993)	ICRU Report 50 1993 -present	ICRU report 62 1999 -present	ICRU report 83 2010 -present
Target Volume	GTV	GTV	GTV
	CTV	CTV	CTV
	PTV	ITV	ITV
		PTV	PTV
Treatment Volume	Treated Volume	Treated Volume	Treated Volume
Organ At Risk	Organ At Risk	Organ At Risk	Organ At Risk
		PRV	PRV
			RVR
Hot spot Area outside target that receives dose >100% of specified target dose : at-least 2cm^2 in a section	Hot spot (Volume outside target that receives dose >100% of specified PTV dose : at-least >1.5cm^2 in a diameter)	Hot spot (Volume outside target that receives dose >100% of specified PTV dose : at-least >1.5cm^2 in a diameter)	High dose RVR
Dose heterogeneity(no value)	Dose heterogeneity (+7% to -5% of prescribed dose)	Dose heterogeneity (+7% to -5% of prescribed dose)	Not specified

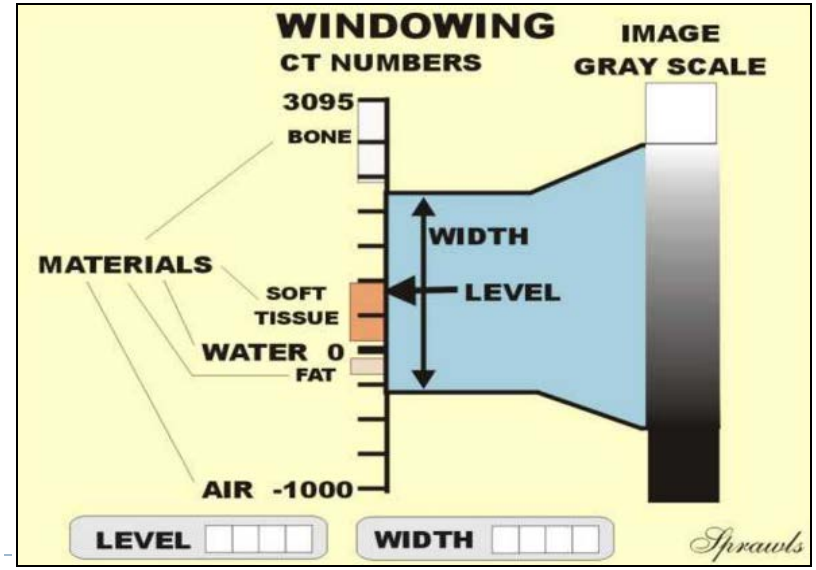
Biological Target Volume



- 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

CT: Primary tool for contouring

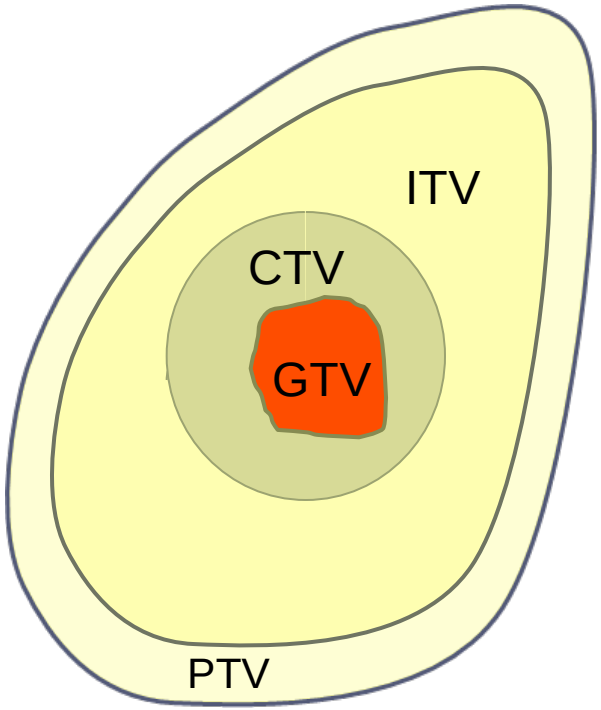
- **Width and Level**
- Each pixel of the reconstructed image is assigned an X-ray attenuation value (CT number/HU).
- CT numbers within one cross-section of the body can thus range from close to -1000 (e.g., the lungs) to several thousand HU (e.g., bone or metal)



Typical Window Settings for Common CT Examinations

Examination	Width	Level
Head		
Posterior fossa	150	40
Brain	100	30
Temporal bone	2,800	600
Neck		
	250	30
Chest		
Mediastinum	350	50
Lung	1,500	−600
Abdomen		
Soft tissue	350	50
Liver (high contrast)	150	30
Pelvis		
Soft tissue	400	50
Bone	1,800	400
Spine		
Soft tissue	250	50
Bone	1,800	400

4D CT



Solution

- **Deep Inspiratory Breath Hold (DIBH)**
- **4DCT**

CT:
2D data set combined to have volumetric dataset

4DCT:

Volumetric dataset**S** for assessing tumor motion

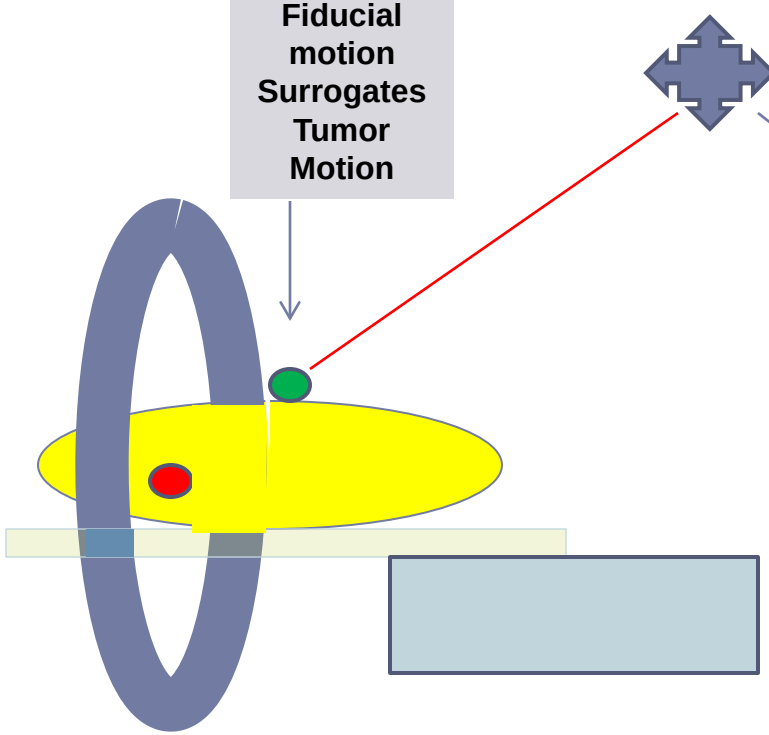
4DCT

- Longer conventional CT Scan

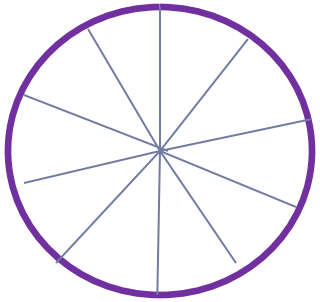
RPM

IR/Laser

Fiducial motion Surrogates Tumor Motion



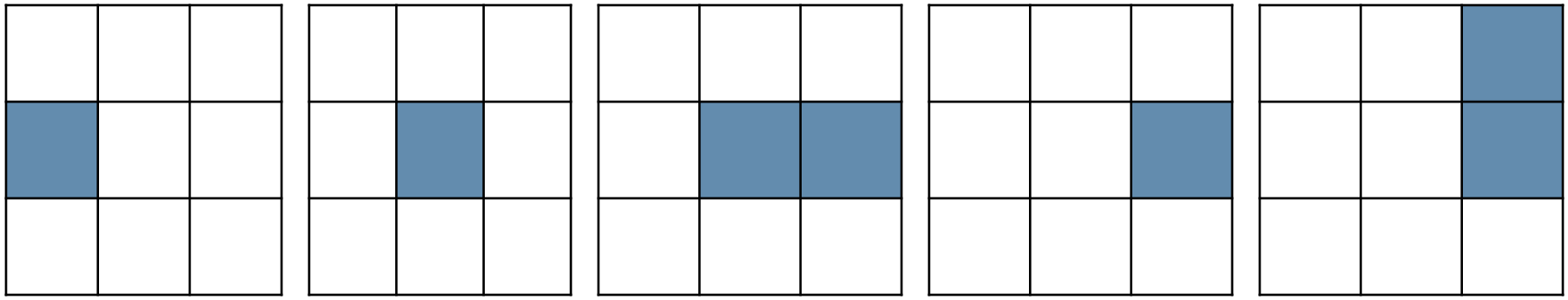
Respiratory cycle



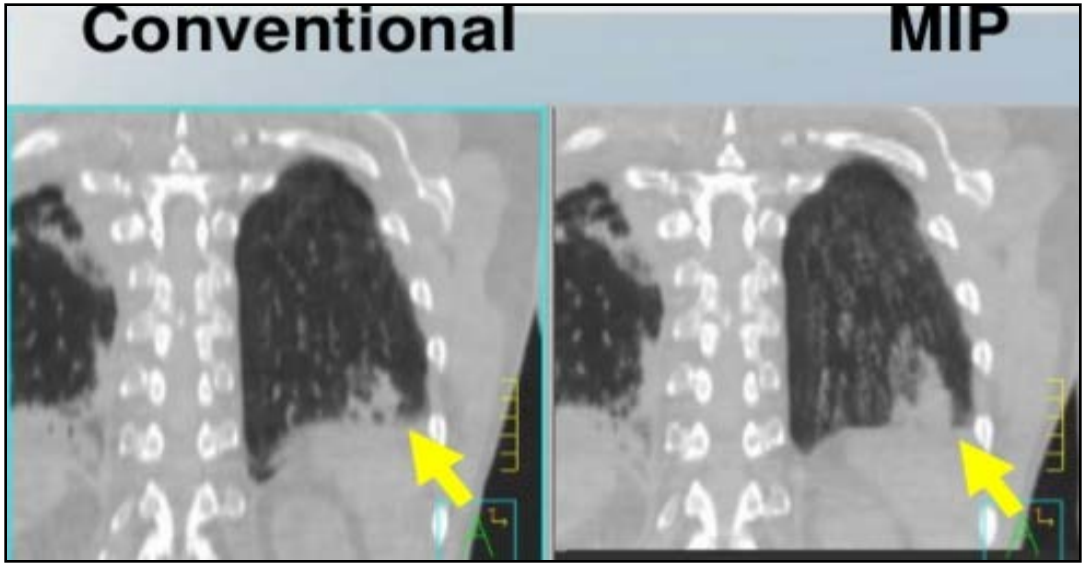
I M A G E D O S E

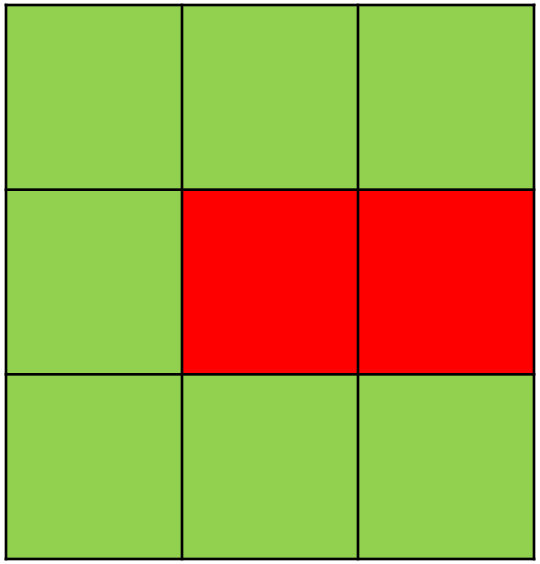
Datasets of
10 divided phases
Or
Equally divided phases of breathing cycle

Contour on Maximum Intensity Projection (MIP)



1 data set to contour GTV (ITV) not 10 data sets





Contouring the primary tumor

- Unfortunately, NO definitive guidelines!
- **GTV**: Gross Tumour Volume (CT/MRI, EUA, clinical examination, PETCT)
- **CTV (customised)** = GTV+1-2cm margin
  - Edited out of air, skin, bone (if no risk of involvement)
  - Edited to encompass entire organ when indicated

- **PTV**= CTV+ 5-7mm margin

EDITING:

- PTV edited out of SKIN to avoid necrosis
- Lower dose volumes out of high dose volumes

Target Volumes

Table 3. Target volume specification for definitive and postoperative IMRT—Washington University guidelines

		Postoperative IMRT	
Target	Definitive IMRT	High risk	Intermediate risk
CTV1	Gross tumor and adjacent soft tissue and nodal regions	Microscopically positive/close margins or nodal region with extracapsular involvement	Surgical bed or nodal region without extra-capsular extension
CTV2	Elective nodal regions	Elective nodal regions	Elective nodal regions

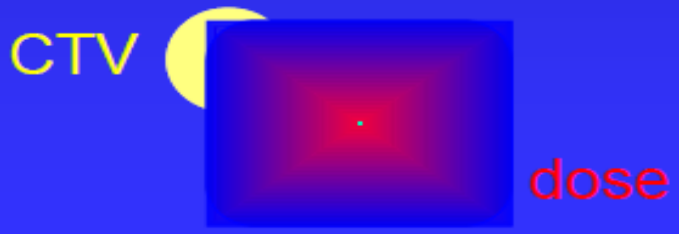
Abbreviations: IMRT = intensity-modulated radiotherapy; CTV = clinical target volume.

PTV Margins and errors

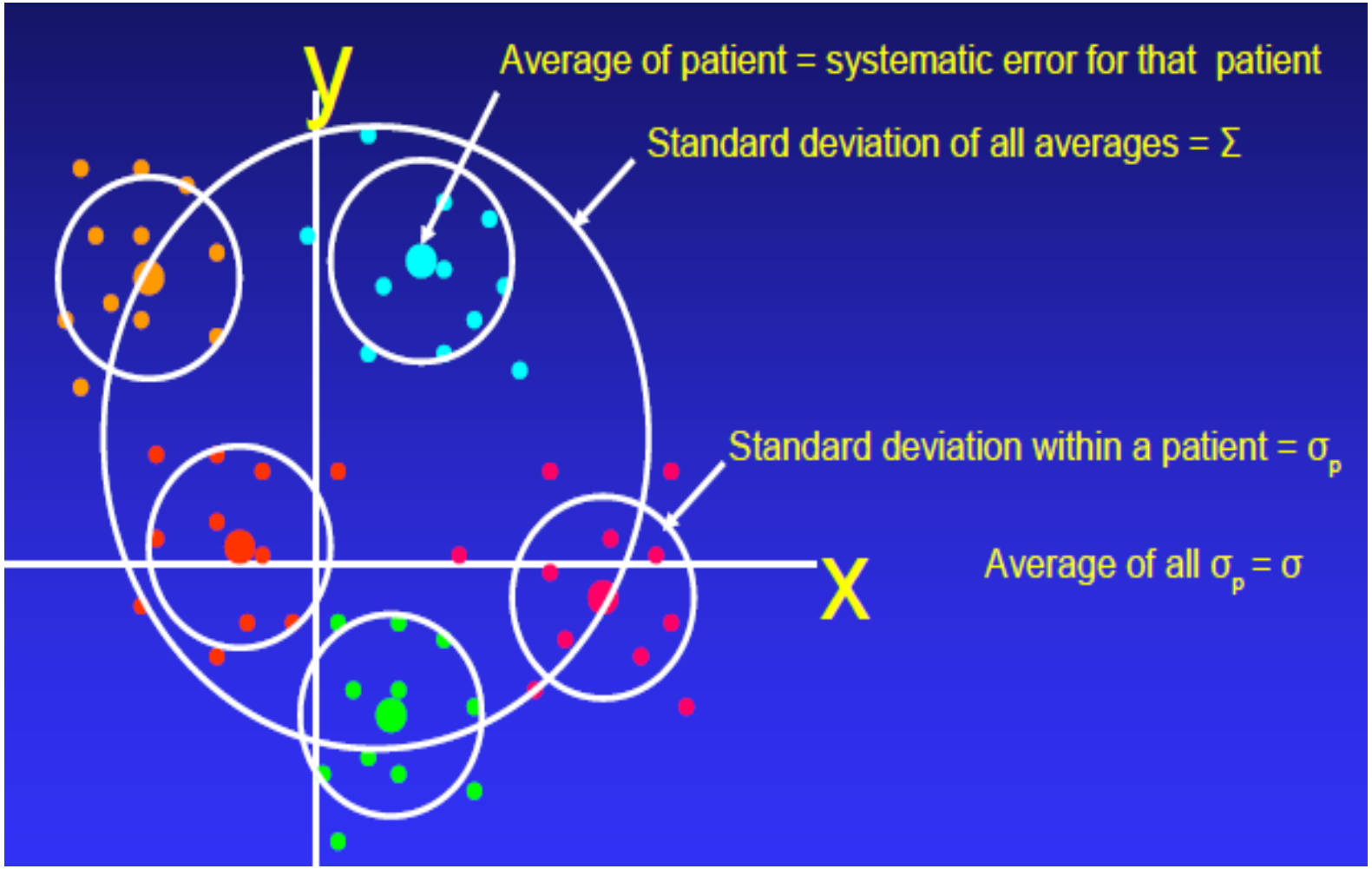
What is the effect of geometrical errors on the CTV dose ?

Treatment execution (random) errors blur the dose distribution

Preparation (systematic) errors shift the dose distribution



Systematic error (Σ) & random error (σ)



Marcel van Hark

Simplified PTV margin recipe for dose - probability

To cover the CTV for 90% of the patients with the 95% isodose (analytical solution) :

PTV margin = 2.5 Σ + 0.7 σ

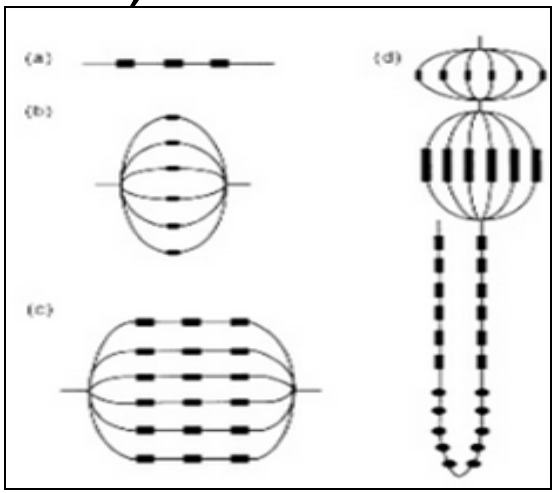
Σ = quadratic sum of SD of all preparation (systematic) errors
σ = quadratic sum of SD of all execution (random) errors

(van Herk et al, IJROBP 47: 1121-1135, 2000)

*For a big CTV with smooth shape, penumbra 5 mm

Organ at risk and Remaining volume at risk (ICRU 83)

- Distinguish between serial like (Spinal cord) and parallel like (eg. Parotid) organs



- **For tubed organ wall contour**

- Remaining Volume at Risk (RVR):

Aids optimization and may assist in evaluating very late effects (e.g. carcinogenesis).

PRV (ICRU 83)

- **A positive OAR to PRV margin for serial organ.**
- **Dose-volume constraints on OAR are with respect to the PRV**
- **Priority rules when overlapping PTVs or PTVPRV(OAR) (in IMRT)**
- **Dose metrics are reported to the PRV**

Treatment Planning

Dose Prescription

- To
- IC

Dose at or near the Centre of the PTV
Dose covering certain % of PTV eg. D95%

Beam selection

- No of beams and angles +/- Non coplanar arrangements
- Couch angle
- Wedge , Block, compensators

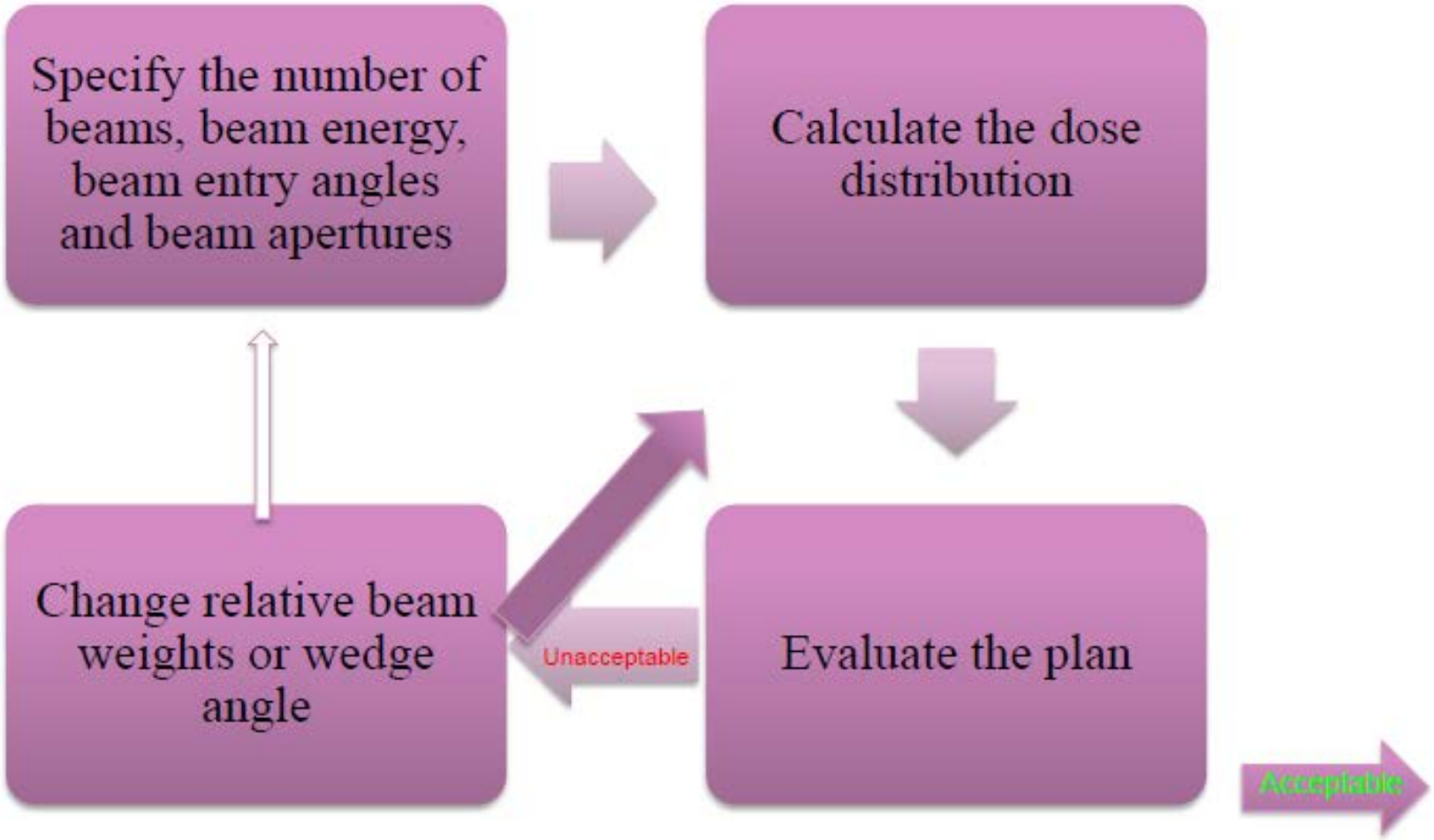
Planning technique

- Forward Planning
- Inverse Planning

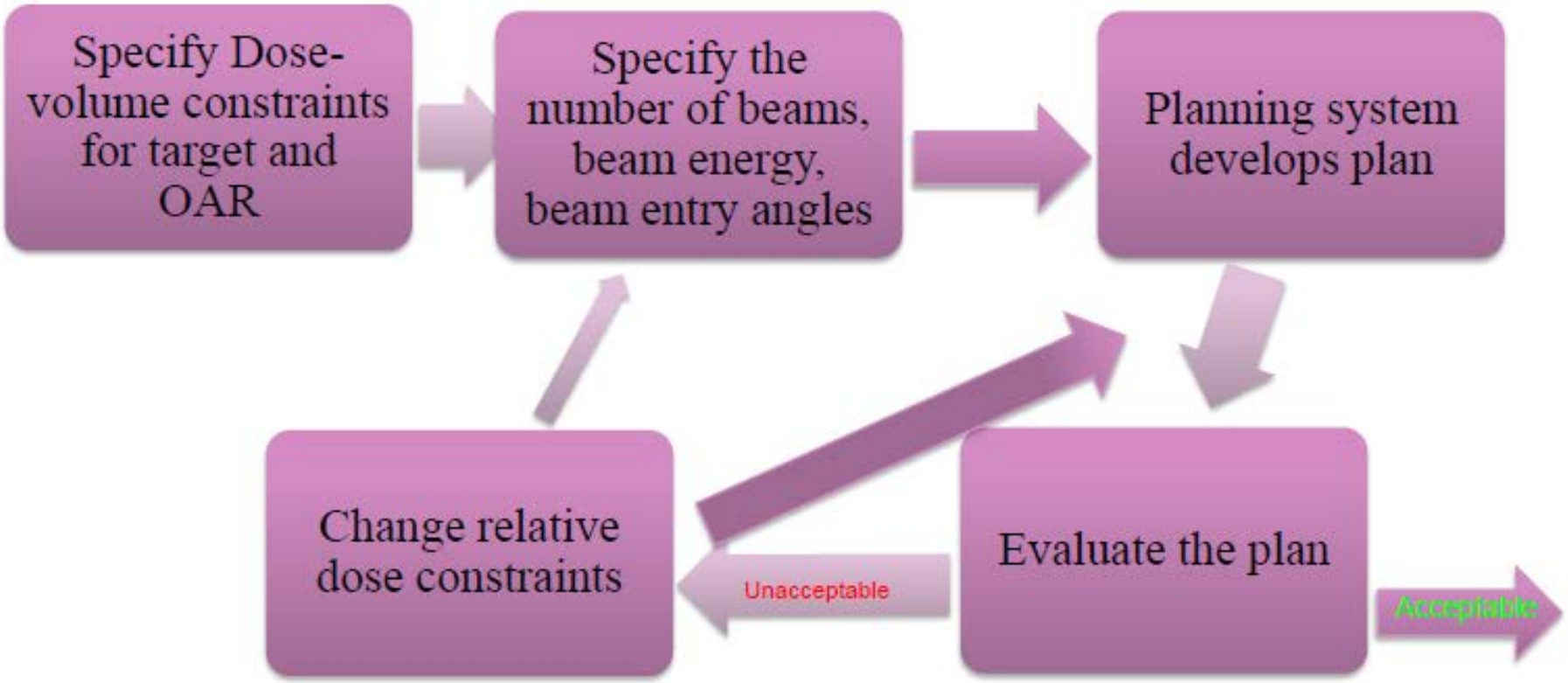
Dose Calculation

- Heterogeneity corrected 3D TPS algorithm
- Convolution/Superimposition/Monte Carlo

Conventional "forward planning" – optimisation loop



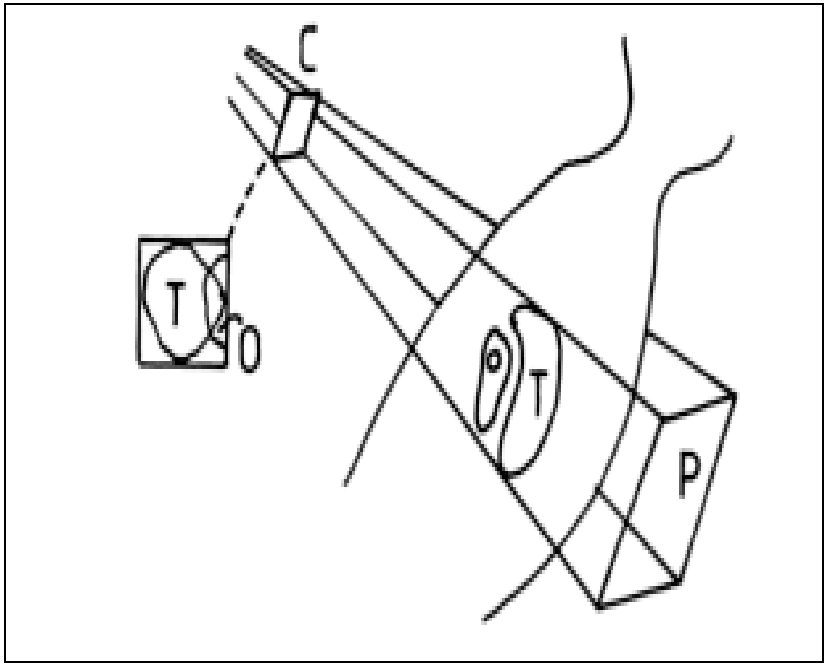
IMRT "Inverse planning"



ESTRO School

BEV,DRR and DCR

- **Beam's Eye View (BEV)**
- Perspective view display from beams source positions
- Useful decision-making tool for shape of blocks /MLCs
- Effective to design optimum direction of beam entry
- Option for viewing target volume +/- OARs

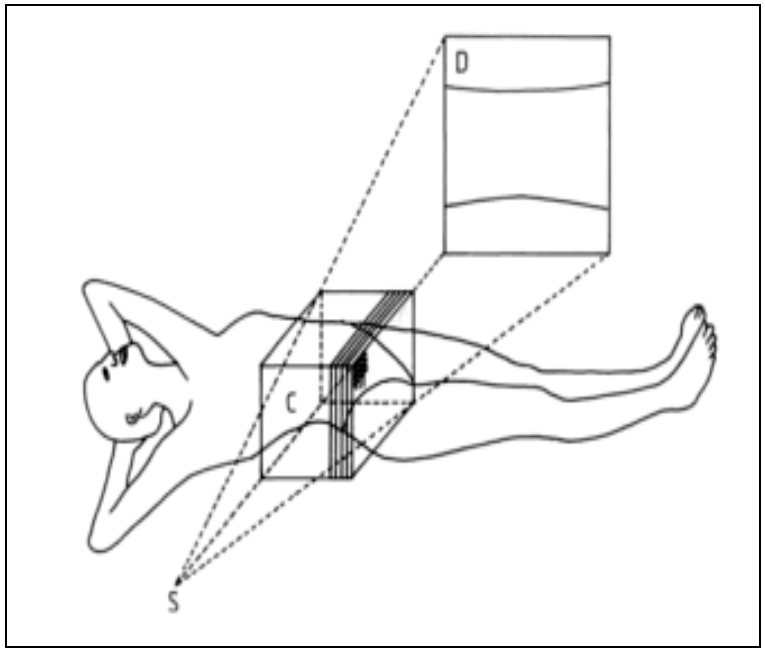


T: Tumor
O: OAR
C : Orthogonal plane w.r.t. beam direction(Plane of BEV construction)
P: Plane of Portal Image

S Webb et.al.

BEV,DRR and DCR

- **Digitally Reconstructed Radiograph (DRR)**
- Reconstructed X ray Image in BEV Plane from CT dataset at planning stage
- Poor resolution
- Shows Target Volume and OAR volumes on computed images
- Matched with portal Image from machine for QA
- Only portal image in situations (OURS!!!)



DRR D generated by X ray tracing from source S through CT data set C virtually in Virtual simulation of 3D TPS

S Webb et.al.

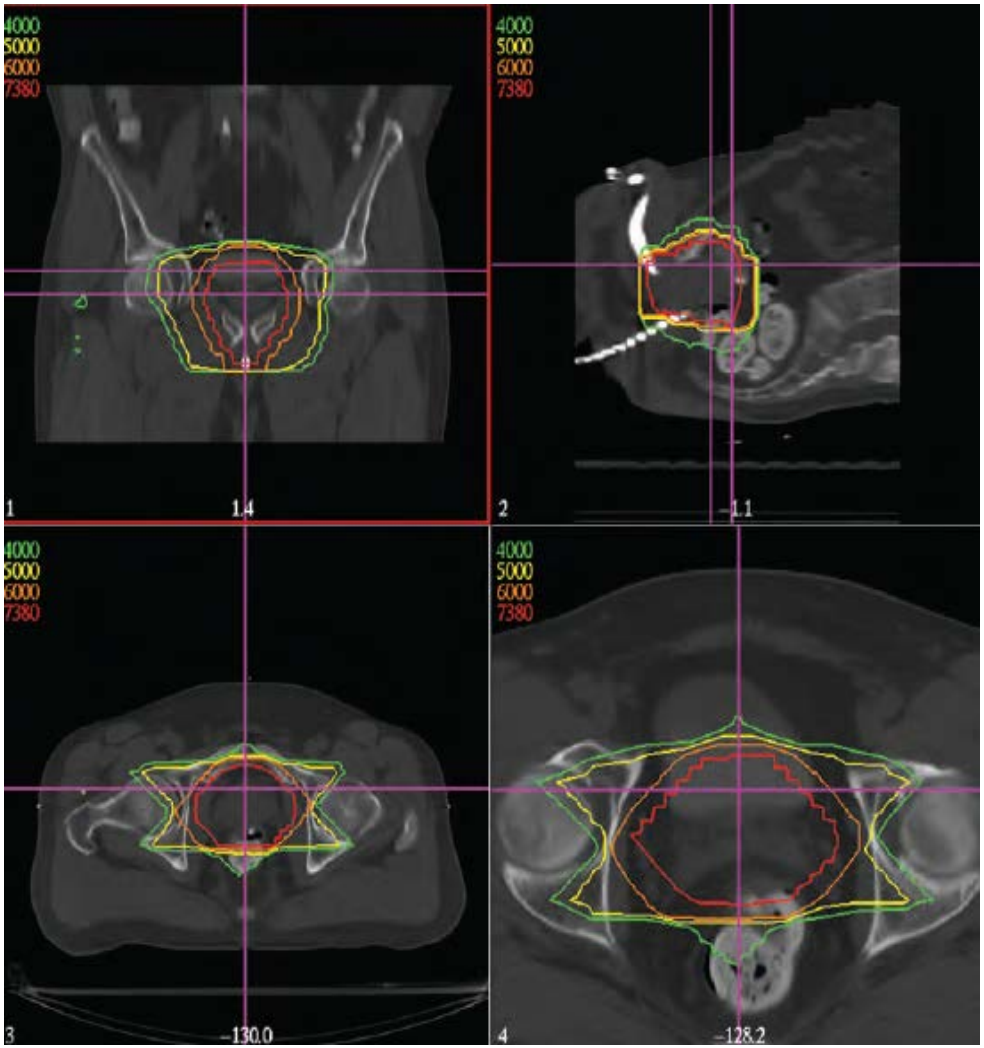
BEV,DRR and DCR

- **Digital Composite Radiograph (DCR)**
- Special type of DRR where different range of HU are selectively **suppressed or enhanced** leaving only images of the organ of interest
- Better visualization of organ of interest

Seymour H Levitt et.al.

Room's Eye View (REV)

- Planner can simulate arbitrary viewing location within treatment room
- Useful tool to choose best gantry, couch and collimator angle for optimum planning
- Isodose surface display(Dose clouds) with real time interplay from any arbitrary viewing angle



Perez and Brady

5.Plan evaluation and Improvement

- **Tools:**

2D multilevel/3D display of Isodose

Color wash

BEV

DRR

DCR

REV (with dose clouds and skin view)

DVH

Dose statistics

Biological models

HI,COIN

Plan acceptance

- Deliverable Beam orientation
- Uniform dose in target volume
- OAR dose under tolerance level
- ICRU constraint definition

Dose Volume Histogram

- Plot that describe the distribution of tissue volumes,v, irradiated by EBRT/ BT with respect to dose D.
- A DVH provides a complete summery of 3D dose matrix

- Type:
  Differential: ΔV(D) / Δ D.
  Cumulative:V (D)
- Utility:
- Planning evaluation – PTV / OR – high dose zone information.

Image based reporting quantities : Definition/DVH

- **YD_x:**

Dose to which X is the **volume** of the structure Y is raised

$CTVD_{90\%}$

Y: absolute/Percent of the structure

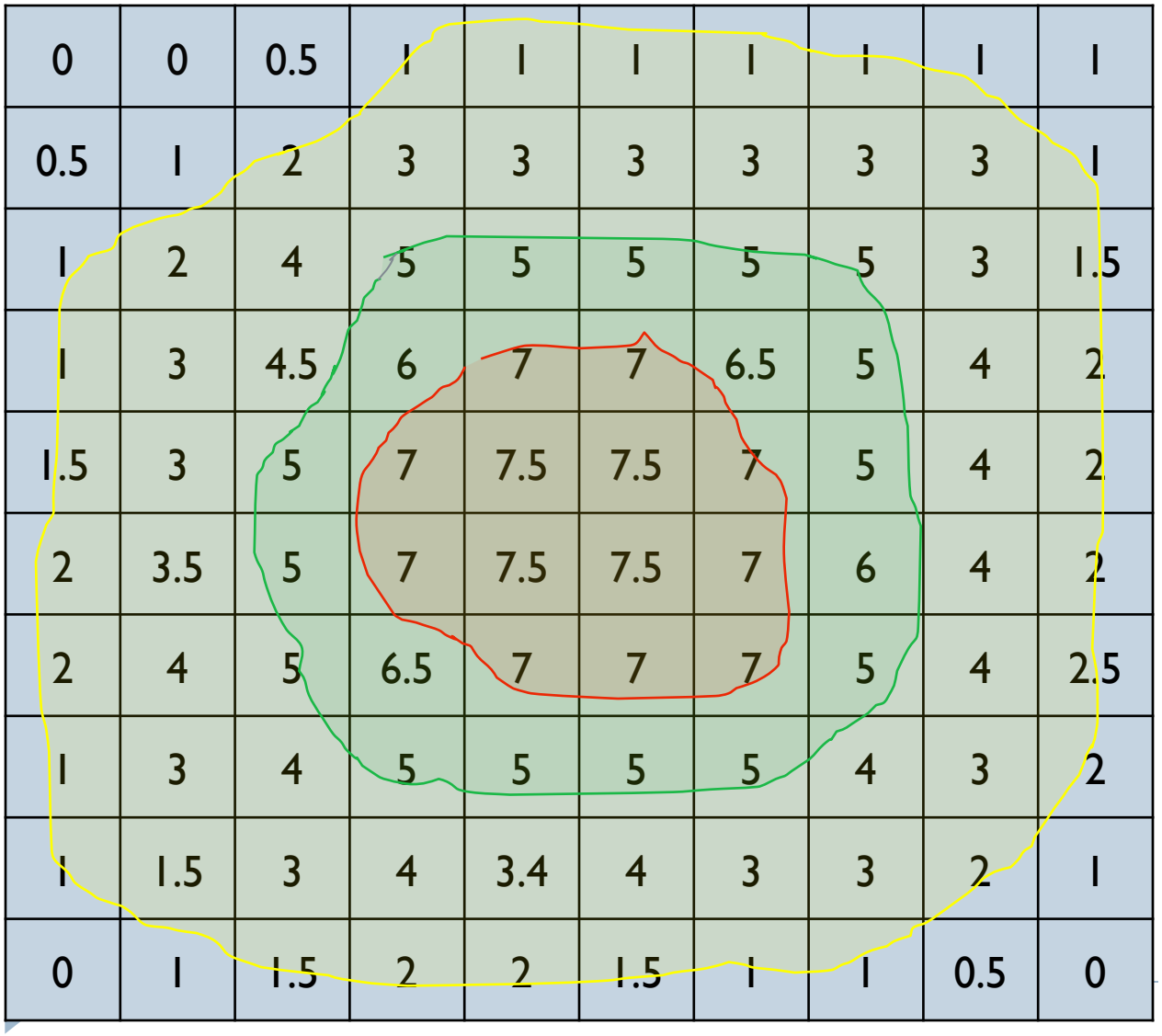
- **YV_x:**

Volume of Y to which X is the dose is raised

$CTV\,V_{60Gy}$

Seymuer H Levitt

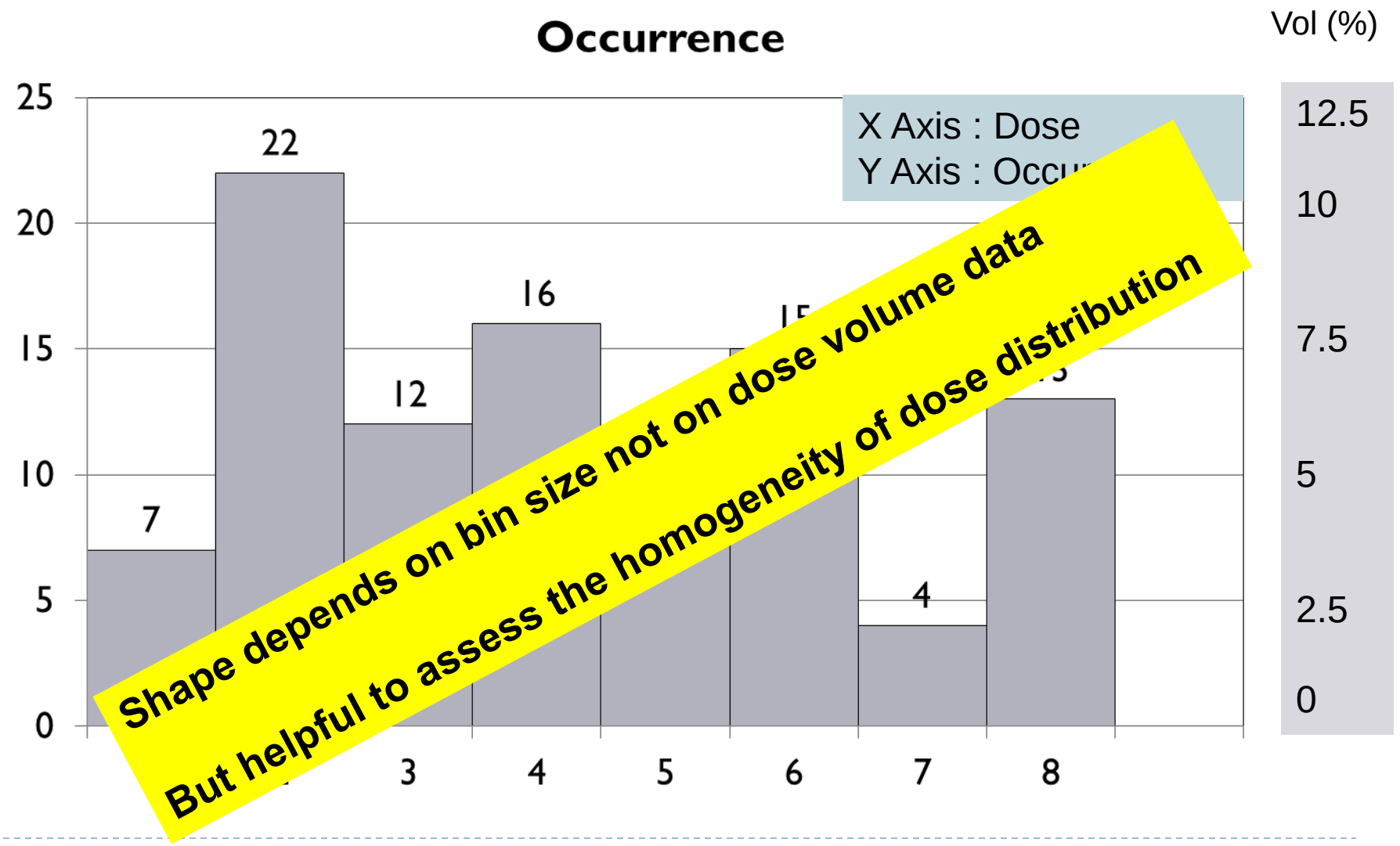
3D grid of voxels in which dose is constant



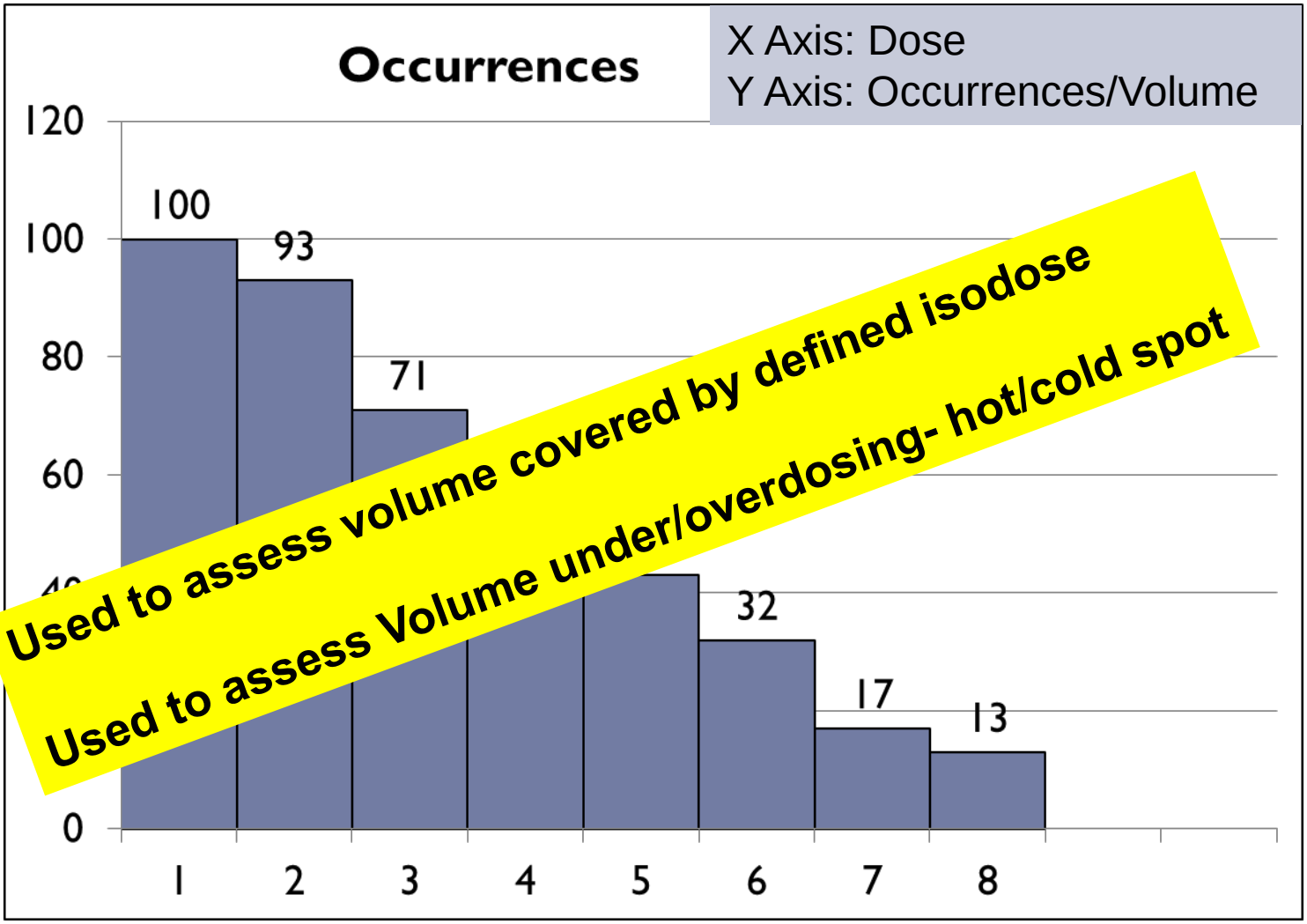
0	0	0.5	1	1	1	1	1	1	1
0.5	1	2	3	3	3	3	3	3	1
1	2	4	5	5	5	5	5	3	1.5
1	3	4.5	6	7	7	6.5	5	4	2
1.5	3	5	7	7.5	7.5	7	5	4	2
2	3.5	5	7	7.5	7.5	7	6	4	2
2	4	5	6.5	7	7	7	5	4	2.5
1	3	4	5	5	5	5	4	3	2
1	1.5	3	4	3.4	4	3	3	2	1
0	1	1.5	2	2	1.5	1	1	0.5	0

Bin	Dose	No
1	0≤ to < 1	7
2	1≤ to < 2	22
3	2≤ to < 3	12
4	3≤ to < 4	16
5	4≤ to < 5	11
6	5≤ to < 6	15
7	6≤ to < 7	4
8	7≤ to < 8	13

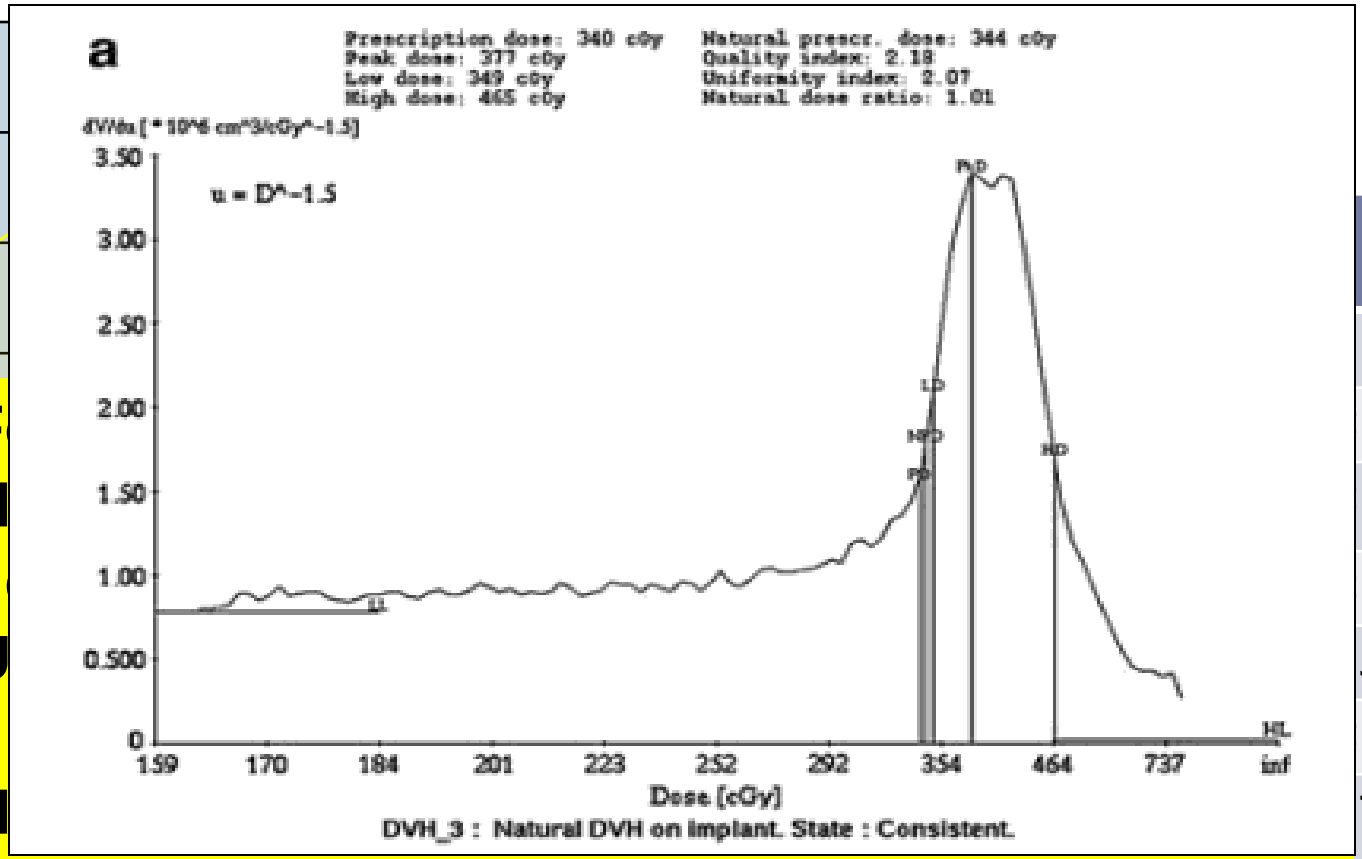
Differential DVH



Cumulative DVH



Natural DVH: Not in EBRT but in BT



F
N
d
U

N

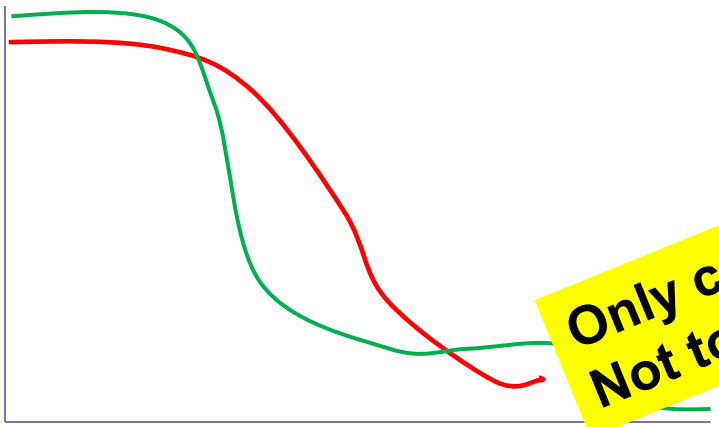
distribution in the volume

0	0								
0.5	I								
I	2								
I									
I.5									
2									
2									
I									
I	I.5	3	4	3.4	4	3	3	2	I
0	I	I.5	2	2	I.5	I	I	0.5	0

	No
I	7
2	22
3	12
4	16
5	11
6	15
7	4
8	13

Seymur H Levitt
Peter Hoskin

Problem with DVH

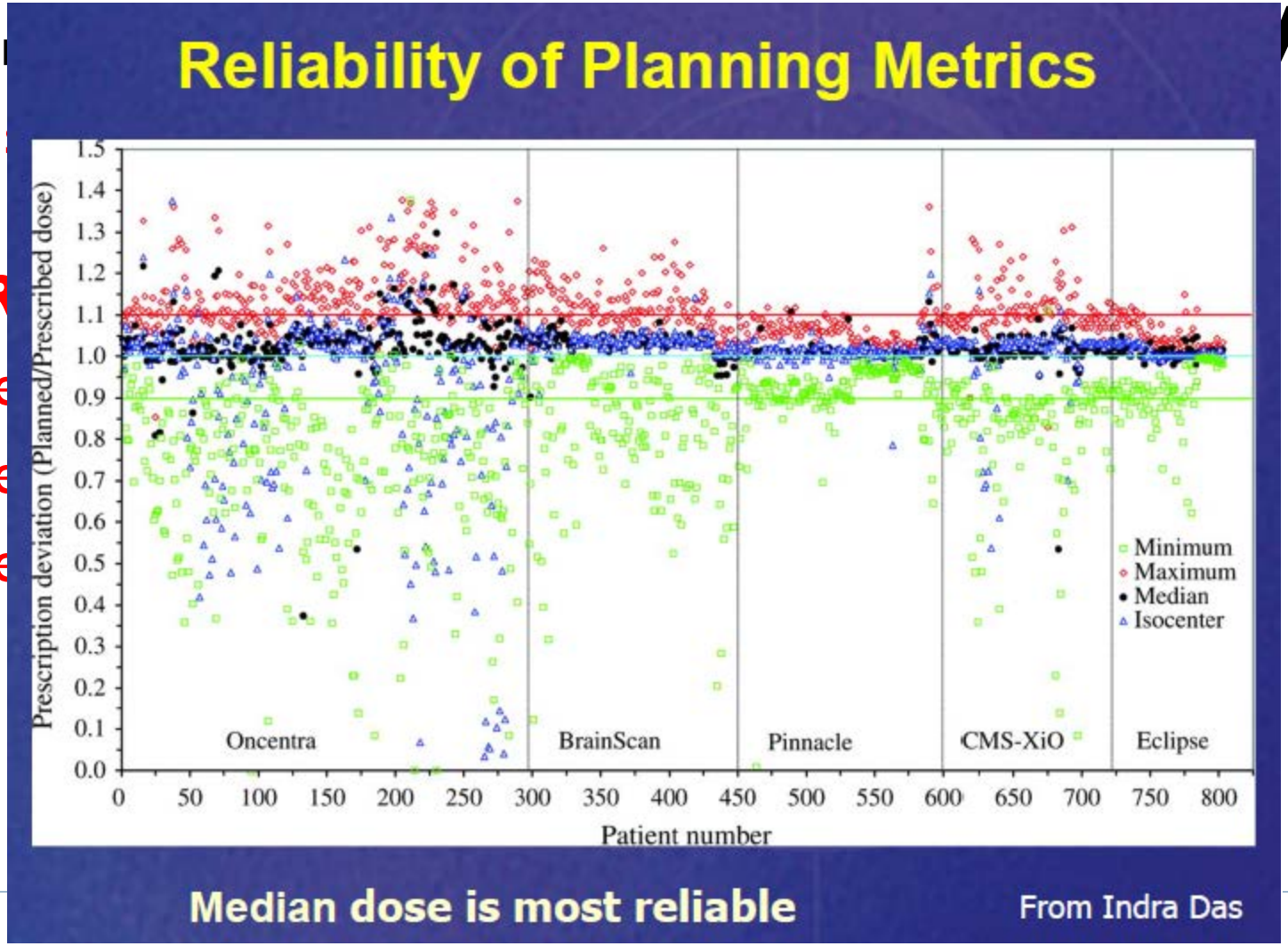


Only compliment
Not to replace spatial dose- distribution

Solution ????:
ICRU Level 3 Dose reporting and assessment:
Biological Models TCP,NTCP and EUD???

Reference Point dose statistics

- Mi
  Di
- ICR
- Ne
- Ne
- Me



PRV dose reporting: ICRU 83

- **Serial Like Organ(eg. Spinal cord):**
- $D_{near\ max} = D_{98\%}$

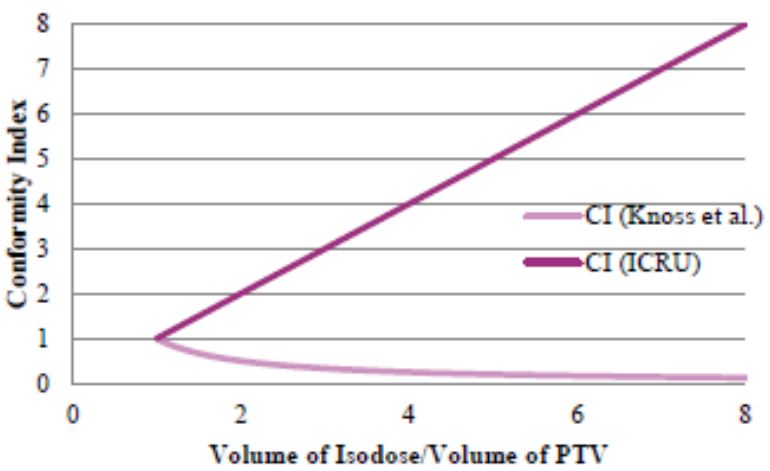
- **Parallel Like organ:**
- D_{mean}
  eg. Parotid mean dose
- V_d = where d refers to dose in Gy
  eg. V_{20} in Lung

Image based reporting quantities : HI

- **Homogeneity Index**
- Fraction of a target volume receiving a dose between the prescription dose and high dose level
- **$HI = CTVV_{100\%} - CTVV_{150\%}$** Saw and Suntharalingam 1998

- **$HI = (D_2-D_{98})/D_p$** is another homogeneity index proposed in ICRU-83, where Dp,D2 and D98 represent the prescribed dose, doses received by 2% and 98% volumes of PTV, respectively

Conformity Index



NOTE:

Conformity index is defined differently in different texts:

RTOG /ICRU:

$$CI = V_{\text{treated to specific Iso-dose}} / V_{\text{target}}$$

The "specific Iso-dose" is often prescription dose, 95% dose or 50% dose

Both definitions CI close to 1 is ideal, provided ALL of PTV is covered.

BE careful not to only look at CI, as lack of PTV coverage may lead to CI near 1.

ESTRO School

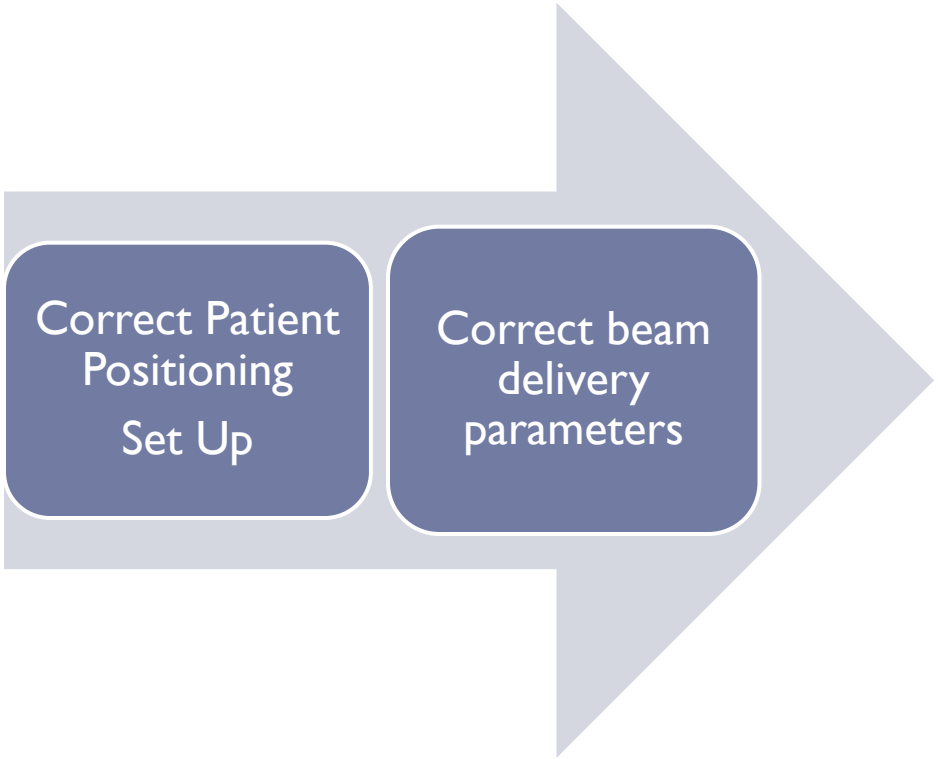
6.a. Plan Implementation and treatment verification

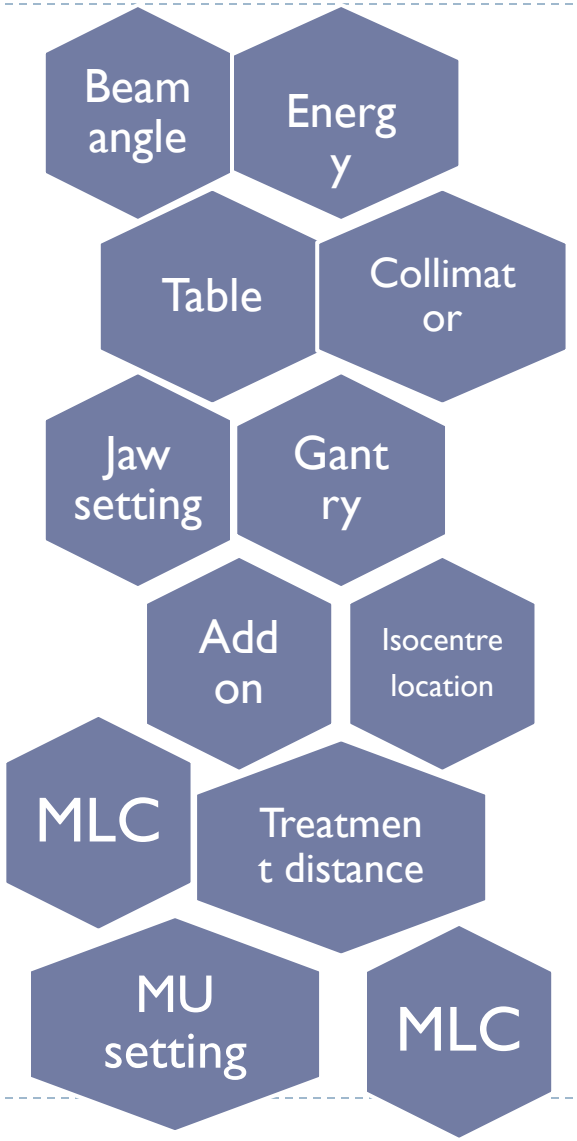
- Documentation of parameters
- Transfer of Data to Electronic Medical Records and Verification and Record system

Must:
1. **DICOM RT format**
2. **Printout copy**
3. **Computer safeguard**

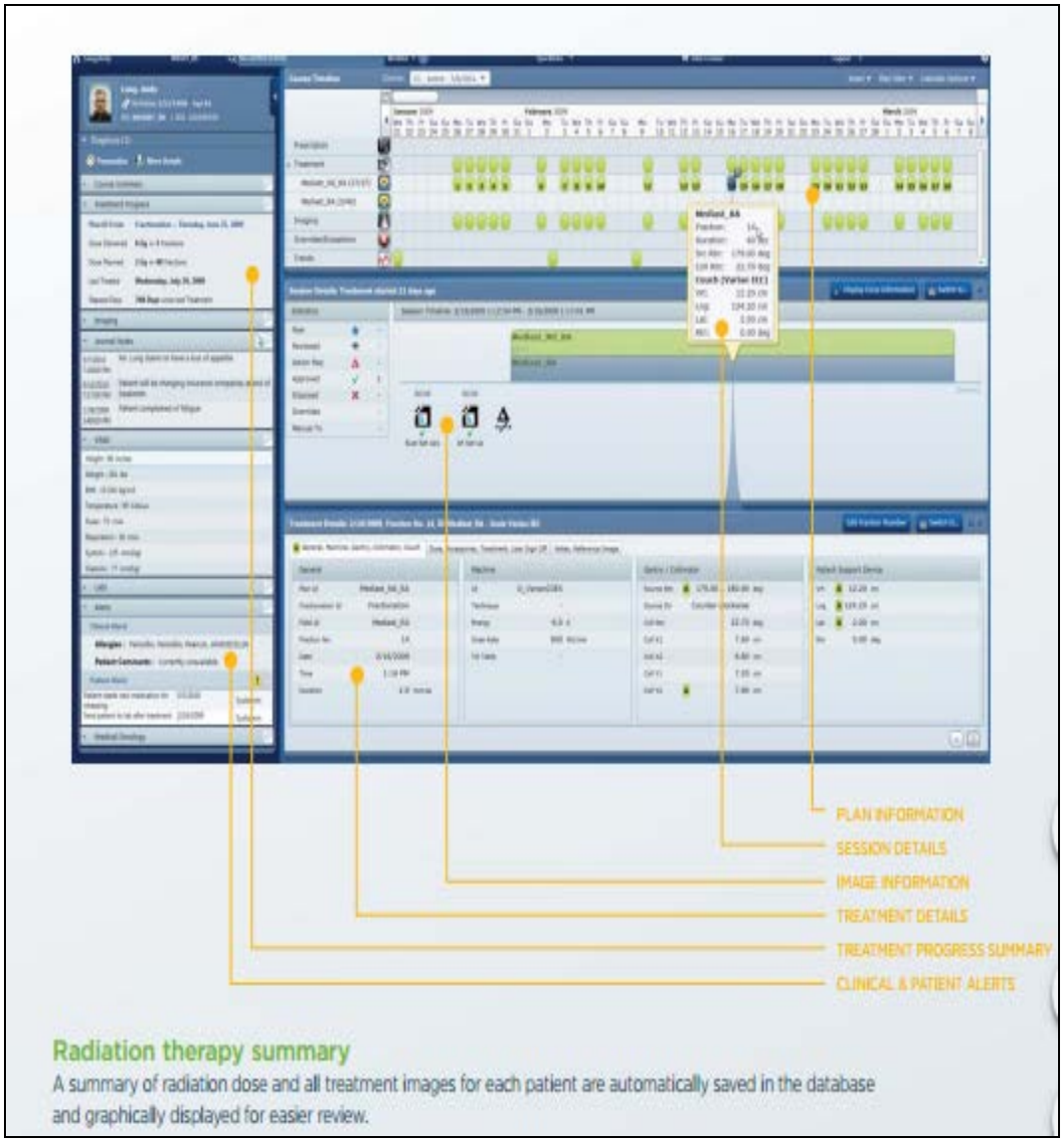
6.a.Plan Implementation and treatment verification

Data Transfer





Radiation Oncology Information System



EMR:

1. **Treatment prescription**
2. **Treatment preparation**
3. **Treatment delivery**
4. **Treatment review**
5. **Chart audits**
6. **Treatment summary**
7. **Data achieving**
8. **Flexible remote access**

ARIA ONCOLOGY INFORMATION SYSTEM

Data recording: ICRU 83

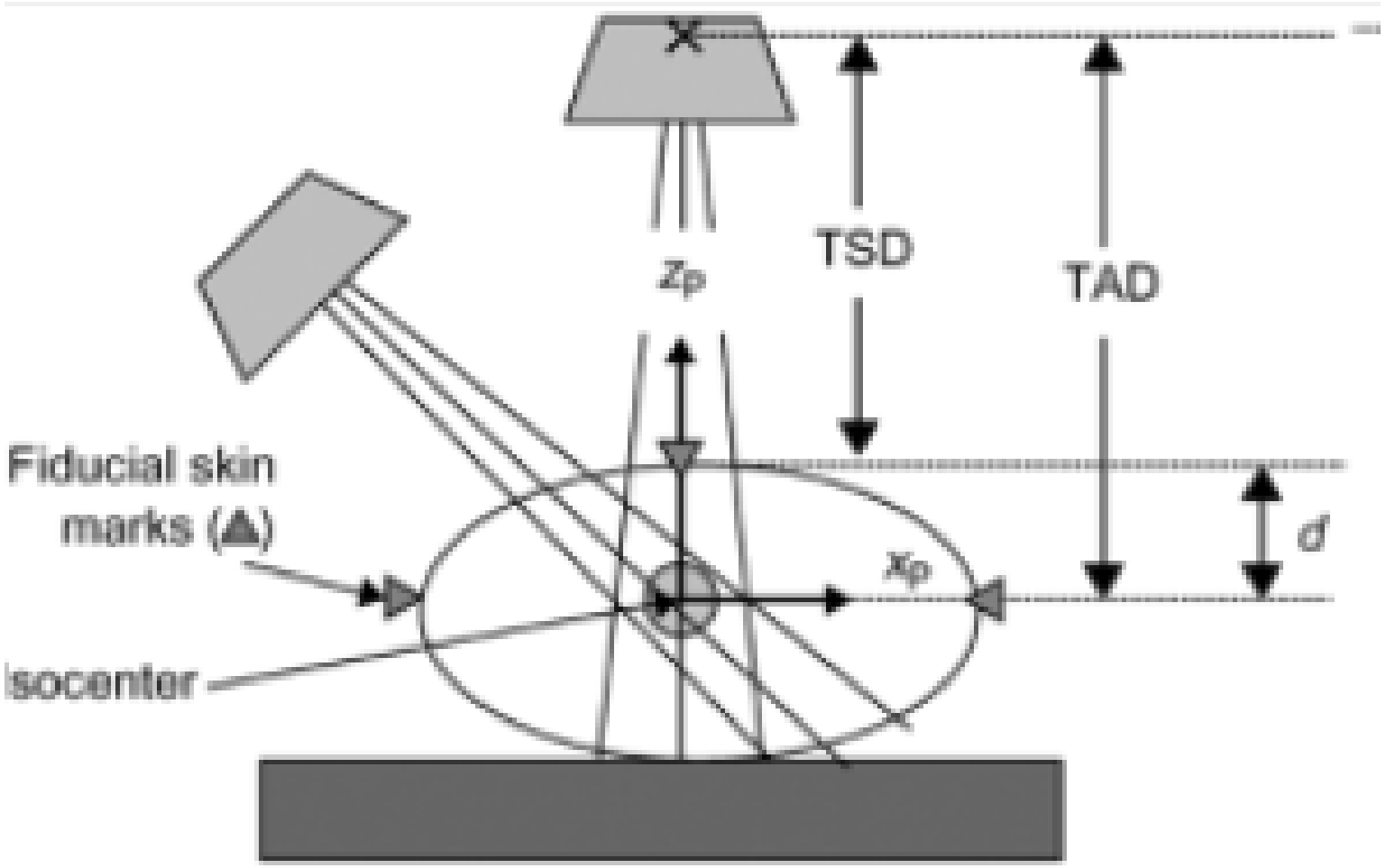
- **Electronic recording of data (IMRT) for the whole life of the patient or 5years which ever is longer**
- **Complete reconstruction of treatment technical data, plan and delivery records**
- **For clinical trials, longer achieving, if scientifically justified**

6.b.Patient setup and verification

- **GENERAL GUDELINES:**

1) Treatments should be set up isocentrically
2) Isocenter position within the patient can be established using the treatment simulator.
3) Thick pads or mattresses should not be used on the simulator table or the treatment table.
4) As far as possible, the patient should be treated in the supine position
5) field boundaries should be defined relative to the bony landmarks established during simulation

Patient Positioning (Simple)



Patient Positioning

Minimum 3 Lasers

- Two of these are mounted on the sidewalls to the patient's left and right
- aligned to be horizontal
- to pass through the machine isocenter
- perpendicular to the isocenter axis.

- Third laser is ceiling mounted and points straight down through the isocenter.

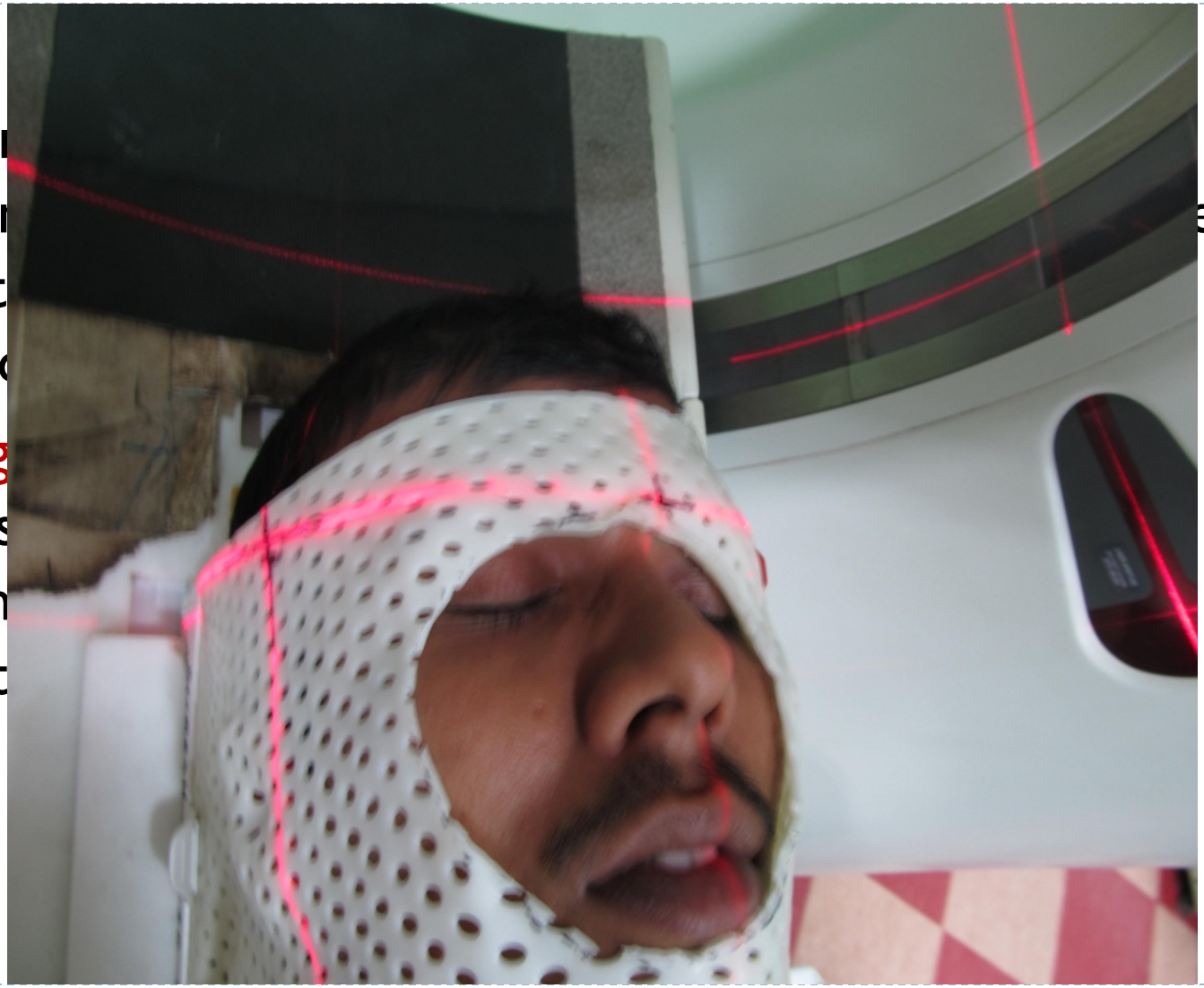
Patient Positioning (Complex)

- Three coordinate systems:

1. The patient coordinate system
2. The room coordinate system
3. Beam coordinate system.

Patient Positioning

- Patie
  patie
  point
  surfa
- Cong
  laser
  impin
  one t

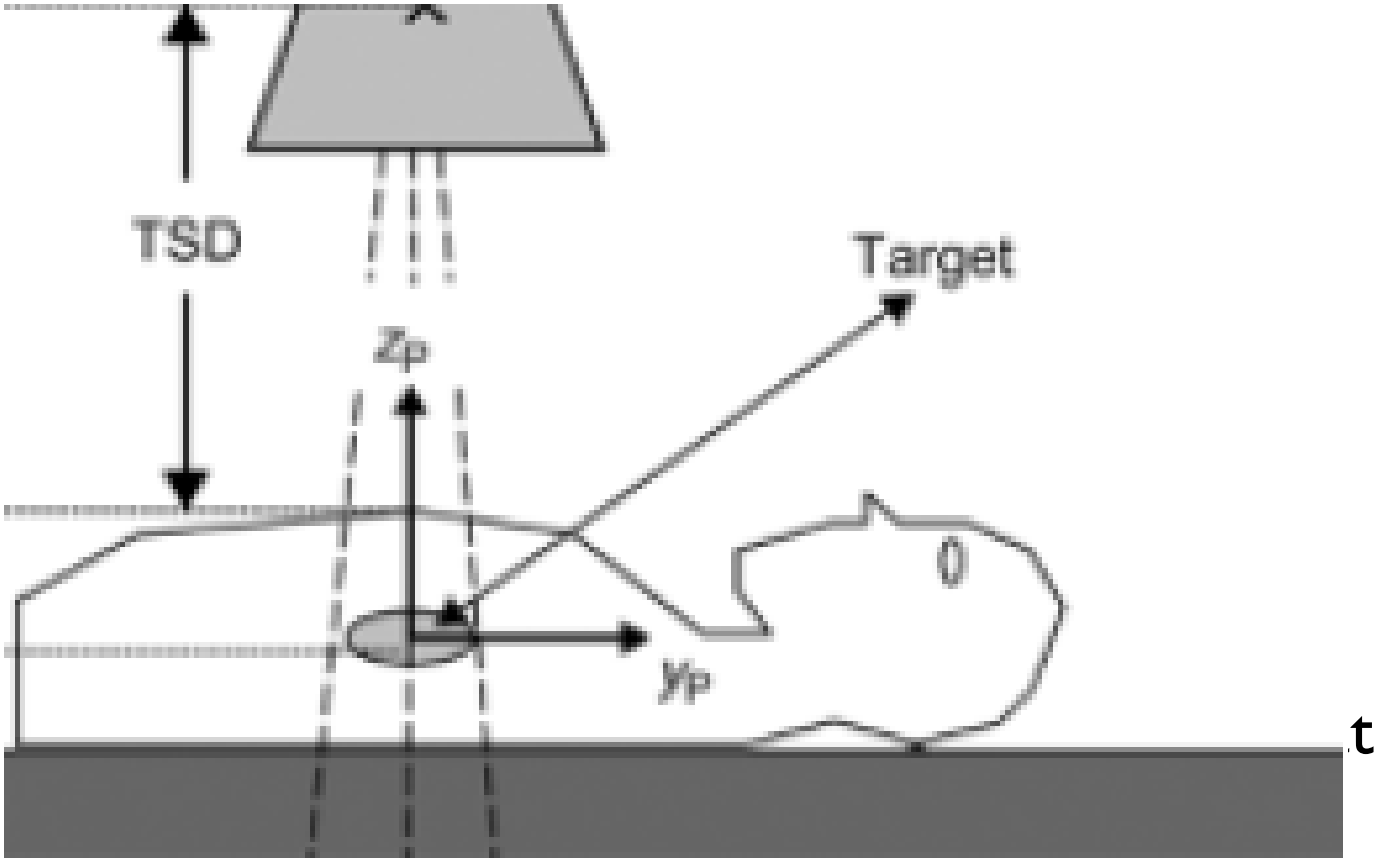


Patient Positioning

- Treatment position:- A comfortable and reproducible position by the patient

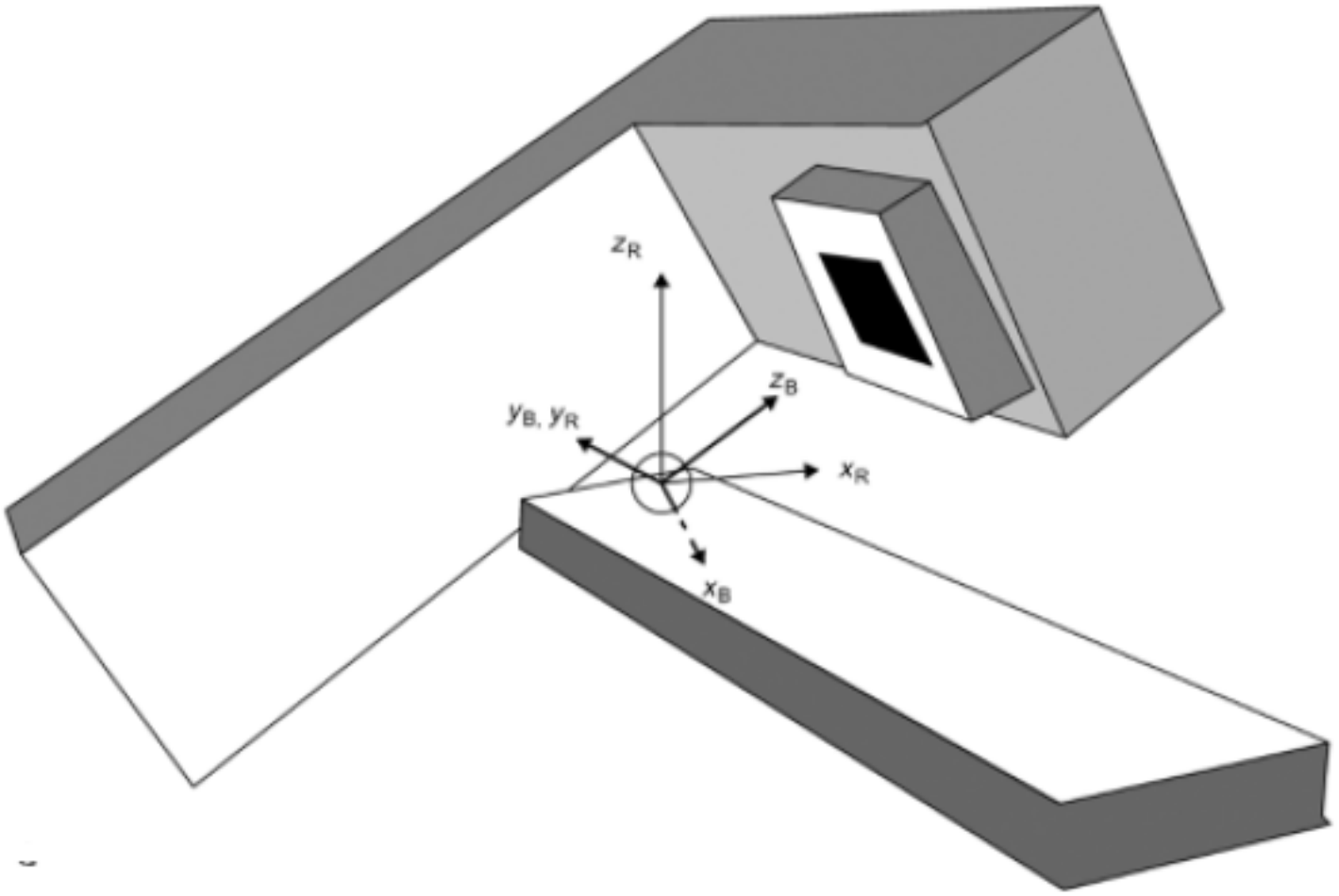
Patient coordinate system

- Patien
  horizo
- A tran
  (pointi
- Anoth
  the xp
  left).
- Treatm
  the ce



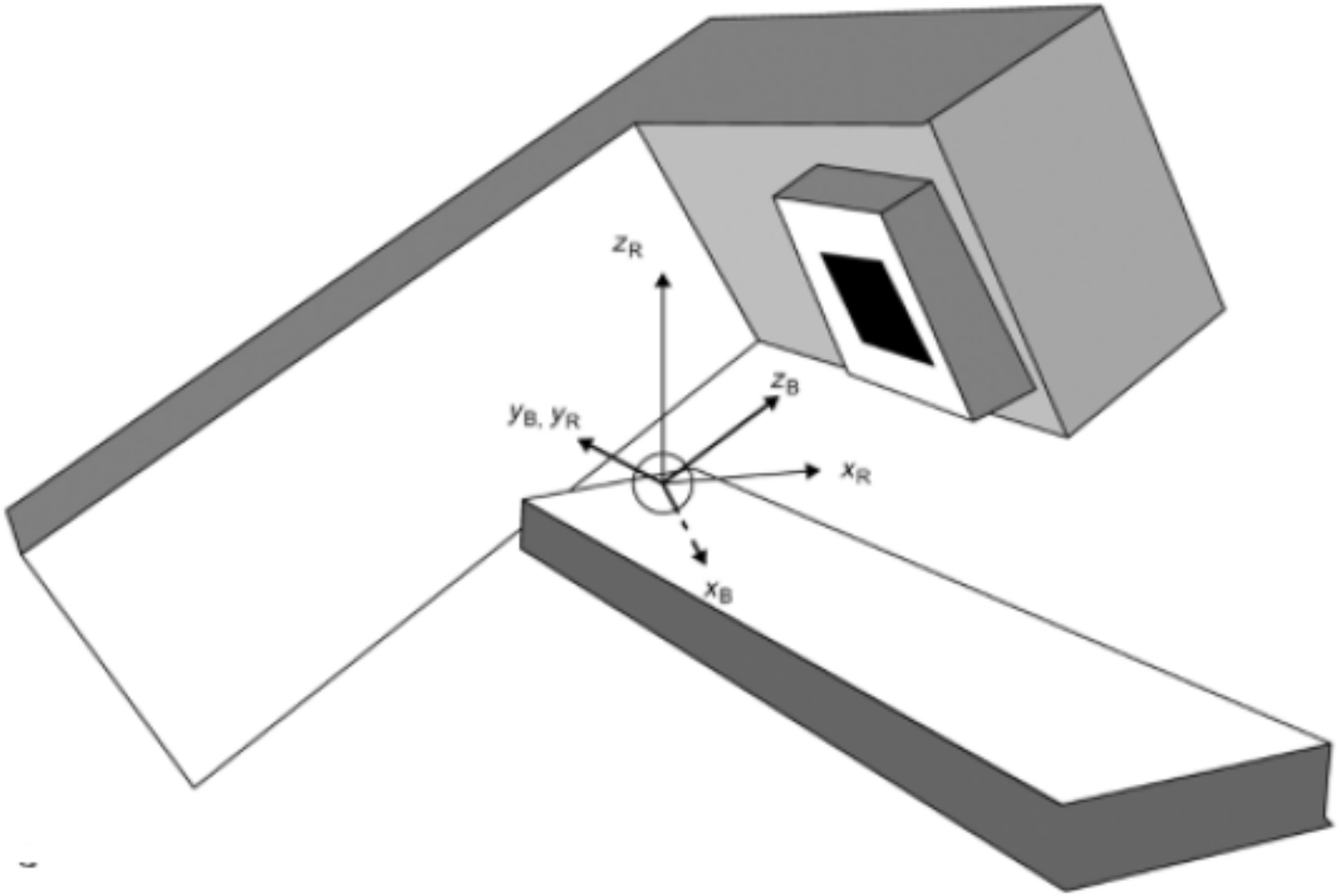
Room coordinate system

- Origin at the isocenter of the Cobalt.
- Y
  p
- P
  pl
- P
- pa



Beam coordinate system.

- Central ray of the radiation beam (zb)
-
-



Patient Positioning & Set Up

- The patient is placed on the couch in the proper treatment position and immobilization devices.

- Shifting the patient on the treatment couch and raising the couch brings the patient coordinate system into alignment with the room coordinate system, as is verified by superpositioning of the orthogonal room lasers with the fiducial skin marks.

Patient Positioning & Set Up

- Ne… …a pie… fac…

MEDICAL COLLEGE HOSPITALS
KOLKATA

P11-217 SHILA SAHA 36Y F Date: 03-11-2011 PIN:
Doctor: Physicist: Dr Kabasi
Tumor site: Breast Cell type: Cell Type
ICD code: TNM class: Comments : Treatment
Treatment: XRT Palliative TELETHERAPY PHASE 1

VIRTUAL SIMULATION FOR PATIENT SETUP

1. **Position patient on couch in treatment position using a fixation device.**
2. **A Reference Mark (and optionally a Verification Mark) should be visible.**
3. **REFEENCE SETUP: Coincide isocenter with reference mark on patient.**
   a. Rotate Gantry to zero degree angle (vertically downwards).
   b. Couch to remain parallel to axis of ganrty rotation - zero degree couch rotation.
   c. Position couch such that central axis of light beam passes through the Reference Mark on the patient.
   d. Adjust the couch such that Reference Mark is 800 mm from the source/virtual source
   e. This is Reference Position of the couch, called ORIGIN for Virtual Simulation setup.

4. **VERIFICATION: Move couch relative to Reference Position (ORIGIN):**
   a. Move couch 233 mm in X direction, 329 mm in Y direction, -65 mm in Z direction
   b. Confirm that Central Axis of light beam passes through Verfication Mark.
   c. Confirm that Verification Mark is 800 mm from the source / virtual source.

5. **BEAM SETUP: Set couch relative to Reference Position (ORIGIN) and gantry/collimator as below:**

	<— COUCH MOVEMENT —>			GANRTY <—	COLLIMATOR —>			VERIFY	
	X-Lat	Y-Vert	Z-Long	Rotation	Angle	Width	Length	Rotation	Blocks	SSD
1	73	39	40	0	60 ~~300~~	66	142	-15	no	757
2	73	39	40	0	240 ~~120~~	65	140	15	no	746

AXES DIRECTIONS: **While viewing the patient from the side of the feet along the couch:**
X-axis is positive pointing towards your right
Y-axis is positive pointing upwards
Z-axis is positive pointing towards you

THIS PROCEDURE IS USED FOR FIELD MARKING AT FIRST SETUP. IT MAY BE REPEATED ANY TIME LATER.

- But, looking at it carefully shows:-

5. BEAM SETUP: Set couch relative to Reference Position (ORIGIN) and gantry/collimator as below:

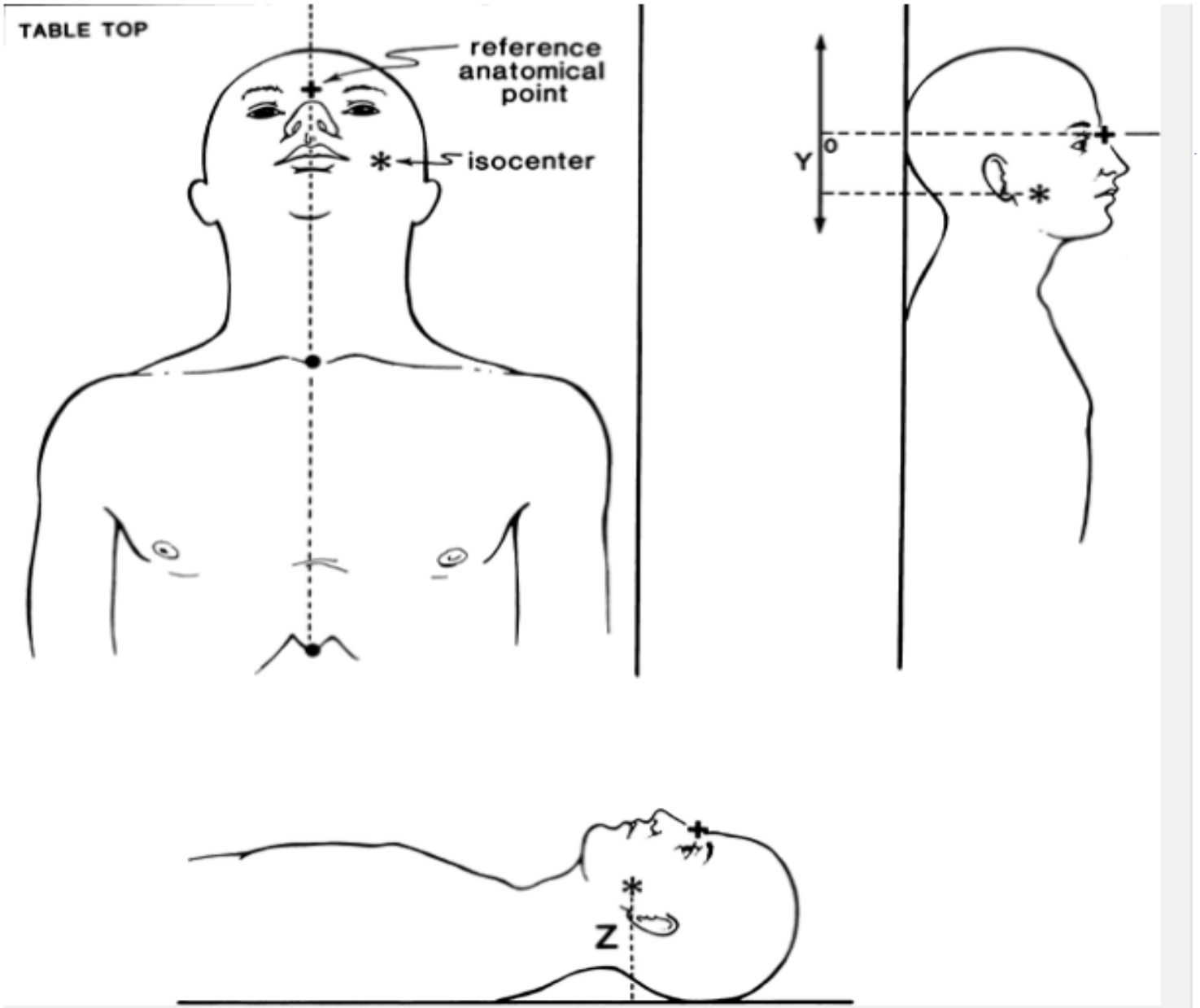
	<— COUCH MOVEMENT —>			GANRTY <——— COLLIMATOR ———>				VERIFY	
	X-Lat	Y-Vert	Z-Long	Rotation	Angle	Width	Length	Rotation	Blocks	SSD
1	73	39	40	0	60 ~~300~~	66	142	-15	no	757
2	73	39	40	0	240 ~~120~~	65	140	15	no	746

AXES DIRECTIONS: While viewing the patient from the side of the feet along the couch:
X-axis is positive pointing towards your right
Y-axis is positive pointing upwards
Z-axis is positive pointing towards you

THIS PROCEDURE IS USED FOR FIELD MARKING AT FIRST SETUP. IT MAY BE REPEATED ANY TIME LATER.

Pat

- M
  sic
  th
- Rc
- Ma
  dia
- O
  ga



A diagram to illustrate X, Y, Z coordinates to a patient set-up.

Plan verification : QA

- Image based verification system

Compare:

EPID ⟶ DRR

CBCT ⟶ Planning CT

To be discussed in IGRT

1. Patient Position
2. Isocentre location
3. Field Shape

Dose delivery verification

Physical dose measurement

- **First day MUST**

External diode/ion-chamber arrays
- MapCheck
- PTW Octavius phantom
- IBA Matrix

Integrated detector systems
- EPID portal dosimetry

T.R. Mackie and V. Gregoire

Quality and Assurance of 3DCRT

- **Program covers whole step from CT scan to delivery**
- **Involving all staffs : RO to RTT**

Machine Specific QA

Patient Specific QA

1.CT Scanner

Check periodically:

- Couch movement and alignment
- Laser co-ordinate system
- Hounsfield CT Number calibration
- Image distortion reporting according to IPEM report 81 when MR fusion is used

Guidelines: Reports of AAPM Task group 66 and IPEM report 81

2. TPS System

- **Periodic QA check according to IAEA TRS-430 report**
- Check calculated vs measured dose
- Test for
- Consistency of input/output data
- MU calculation
- Relative dose distribution
- Geographical data eg. BEV, FOV display
- Plan evaluation tool eg. DRR, DVH

3.Treatment machine with MLCs

- IPEM report 81,AAPM Task group 50 and SFPM report 20
- **Leaf calibration:**
- **Test**
- Mean position of whole leaves(Bank)
- Mean position of Individual leaf (Minor offset)
- Leaf position w.r.t. position of any back up Jaw
- Leaf alignment in different position (rounded leaf specially)

Leaf calibration test procedure is vendor specific

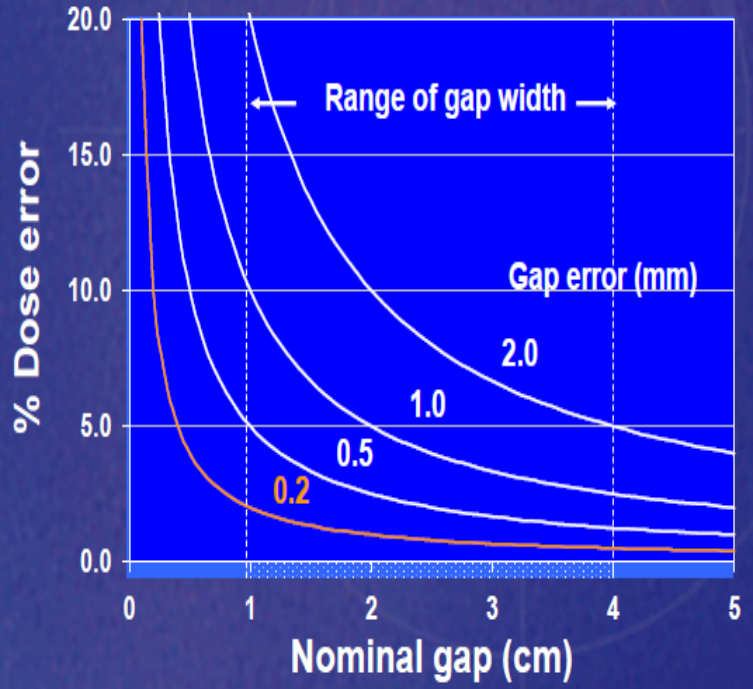
5% non uniformity in leaf positions found in single exposed film represents error of 0.5mm

IAEA TecDoc 2008

Other issues in MLC QA

Gap Error is Fundamental fo Conventional MLCs

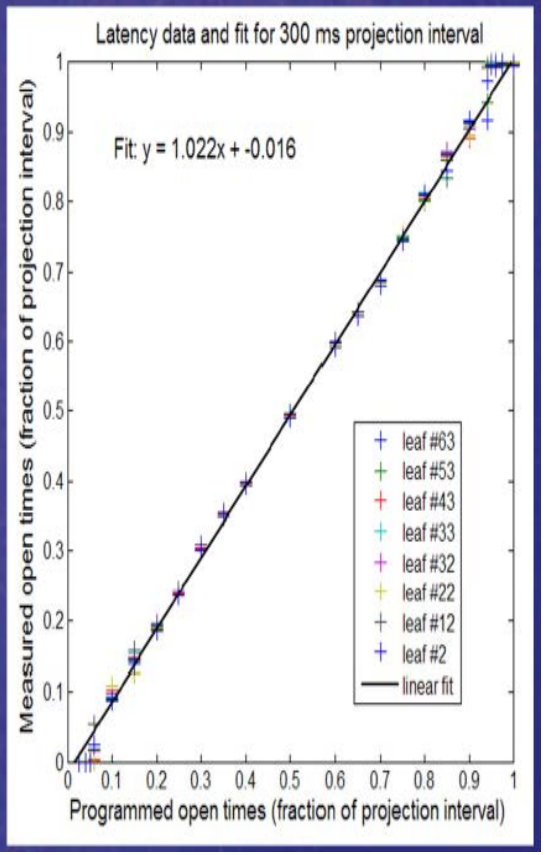
Gap error → Dose error



From Tom Losasso, Memorial Sloan Kettering

Leaf Latency is Fundamental fo Binary MLCs

- TomoTherapy uses linear fit of measured data to model leaf latency
- Plans with small opening times lead to uncertainty in delivery – also leads to delivery inefficiencies



V.Gregoire

3. Patient Setup

- "Patient setup 3-D CRT can only be successful if the patient is set up in the same position for each fraction and **should not** be carried out unless portal imaging is available (either with film or an EPID)."

  IAEA TECDOC 1588

- Internal organ motion managing principles

  Bladder and rectal filling

  Respiratory motion management strategies

- CTV to PTV margin based on **local audit** of setup accuracies

4.Dosimetry

QA of Individual Fields

External diode/ion-chamber arrays

- MapCheck
- PTW Octavius phantom
- IBA Matrix

Integrated detector systems

- EPID portal dosimetry

V.Gregoire

GORTEC
Groupe Oncologie Radiothérapie Tête Et Cou
Radiotherapy oncology group for head & neck

Gortec IMRT Test Phantom

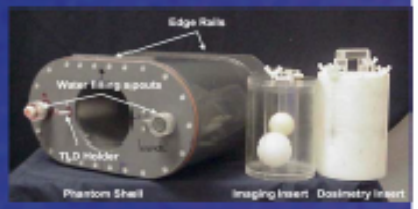
TLDs are placed at seven locations.

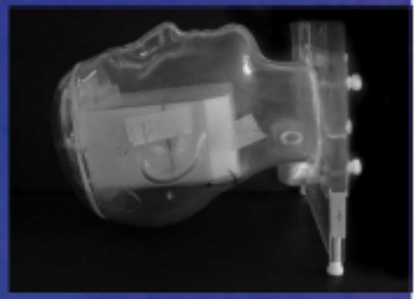
- Point 1: Isocenter
- Point 2: Spinal cord isocenter
- Point 3: Spinal cord cranial
- Point 4: PTV T R
- Point 5: PTV T R cranial
- Point 6: PTV N L
- Point 7: PTV N L caudal

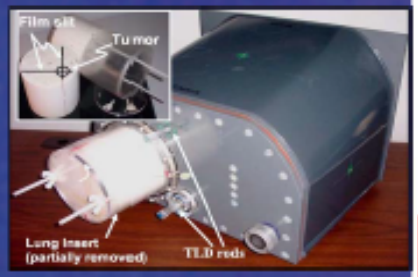
Courtesy M. Tomsej, Brussels

V.Gregoire

IMRT Evaluation using Anthropomorphic Phantoms







Molineu *et al* IJROBP 2005
Ibott *et al* Tech in Ca RT 2006
Followill *et al* Med Phys 2007

Phantom Results

Comparison between institution's plan and delivered dose.

Criteria for agreement: 7% or 4 mm DTA (5%/5mm for lung)

Site	Institutions	Irradiations	Pass	Fail
H&N	472	631	75%	25%
Pelvis	108	130	82%	18%
Lung	67	77	71%	29%
Liver	15	18	50%	50%

For H&N, using a criteria of 5% or 4mm, the passing rate drops from 75% to 58%

Courtesy Ibott, RPC

Comparative Methodology & Tools Of basic CRT versus 3D CRT

	Level 1 Basic CRT	Level 2 3-D CRT
1. Patient data acquisition		
Immobilization	Desirable	Customized to the patient
Imaging system	Localization films, few CT slices optional	Thin adjacent CT slices, MR optional
Anatomical data		
Reference marks for setup	Height above table and skin marks	External markers or frame
Critical organs	Contour individual slices	3-D segmentation
Inhomogeneities	Optional	Contouring every slice or voxel based correction
Gross tumour volume (GTV)	May not be formally defined	Contouring every slice
Clinical target volume (CTV)	May not be formally defined	Grown from GTV using auto-margin growing
Internal target volume (ITV)	May not be formally defined	Based on standard decision rules
2. Beam definition		
Accounting for beam setting uncertainty	Margins are not customized	3-D margins based on audit of setup errors
Type of radiation and beam modifiers	Photons or electrons ± wedge filters	Photons, wedges, field in field, compensators
Beam incidence	Coplanar beams	Several (including non-coplanar) beams
Isocentre	SSD or SAD technique	SAD technique (auto centred on target)
Beam limiting device	Non-customized shielding blocks	Customized blocks or MLC
PTV – CTV margin	Shape drawn on simulation films	Protocol margins based on audit

IAEA TECDOC 1588

	Level 1 Basic CRT	Level 2 3-D CRT
3. Dose calculation and optimization		
Calculation model	1-D or 2-D (slice) ± inhomogeneity	2-D or 3-D with inhomogeneity
Evaluation of treatment plans	Isodoses on central slice or several slices	Isodoses viewed in 3-D on computer + DVH
Treatment plan optimization	Successive trials + visual appreciation	Successive trials + simple optimisation
4. Treatment verification and execution		
Verification simulation	Normal practice	Useful
Immobilization (see above)	Desirable	Customized to the patient
Aids for positioning	Lasers + light field	Isocentre lasers
Patient positioning	Height above couch + skin marks	Move from anatomical reference or stereotaxy
Verification reference image	Simulation film	DRR
Record and verify system	Desirable	Essential but network is optional
In vivo measurements	Desirable	TLD or diodes recommended


GAD MFA 108 SAL
STA CRUZ