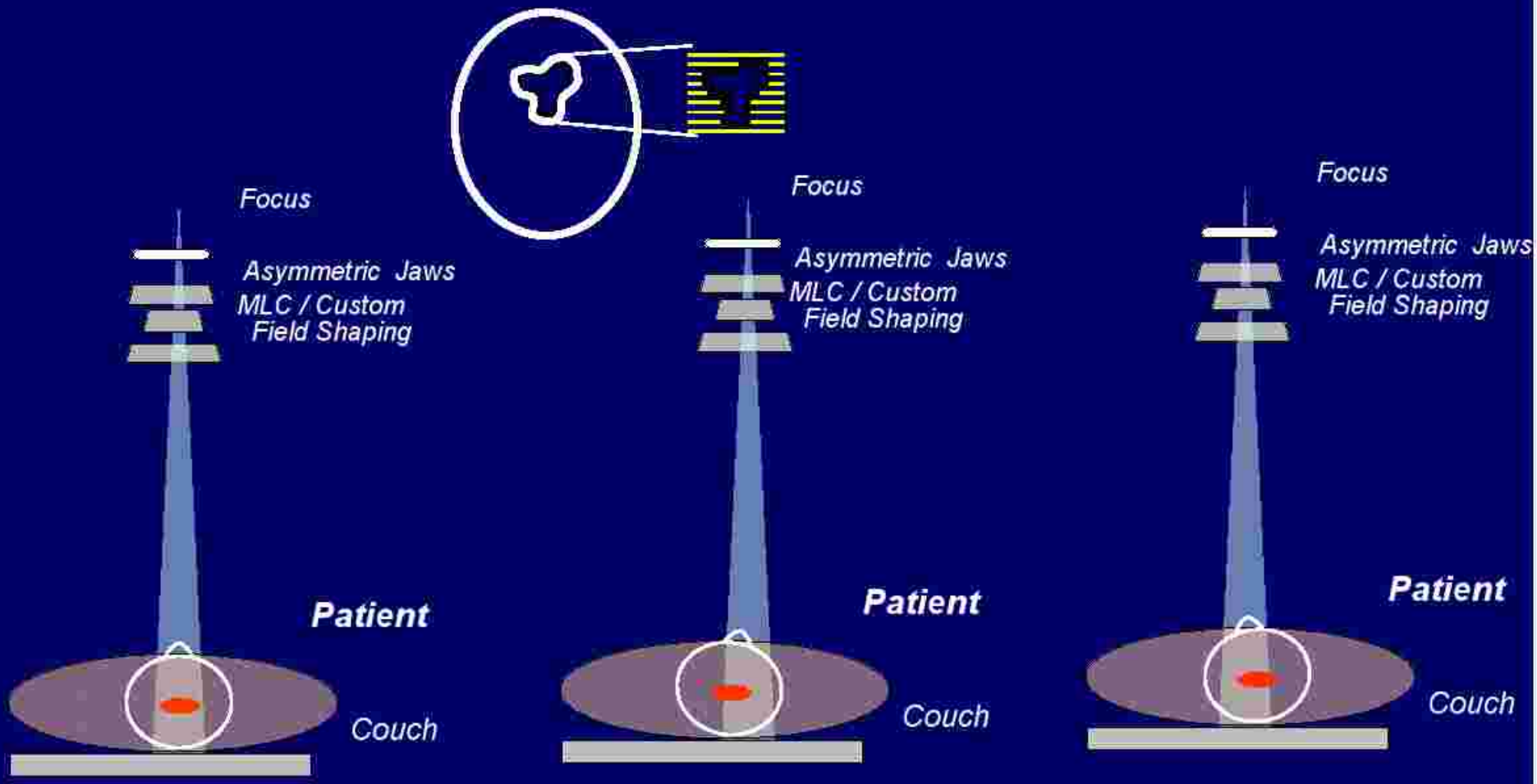
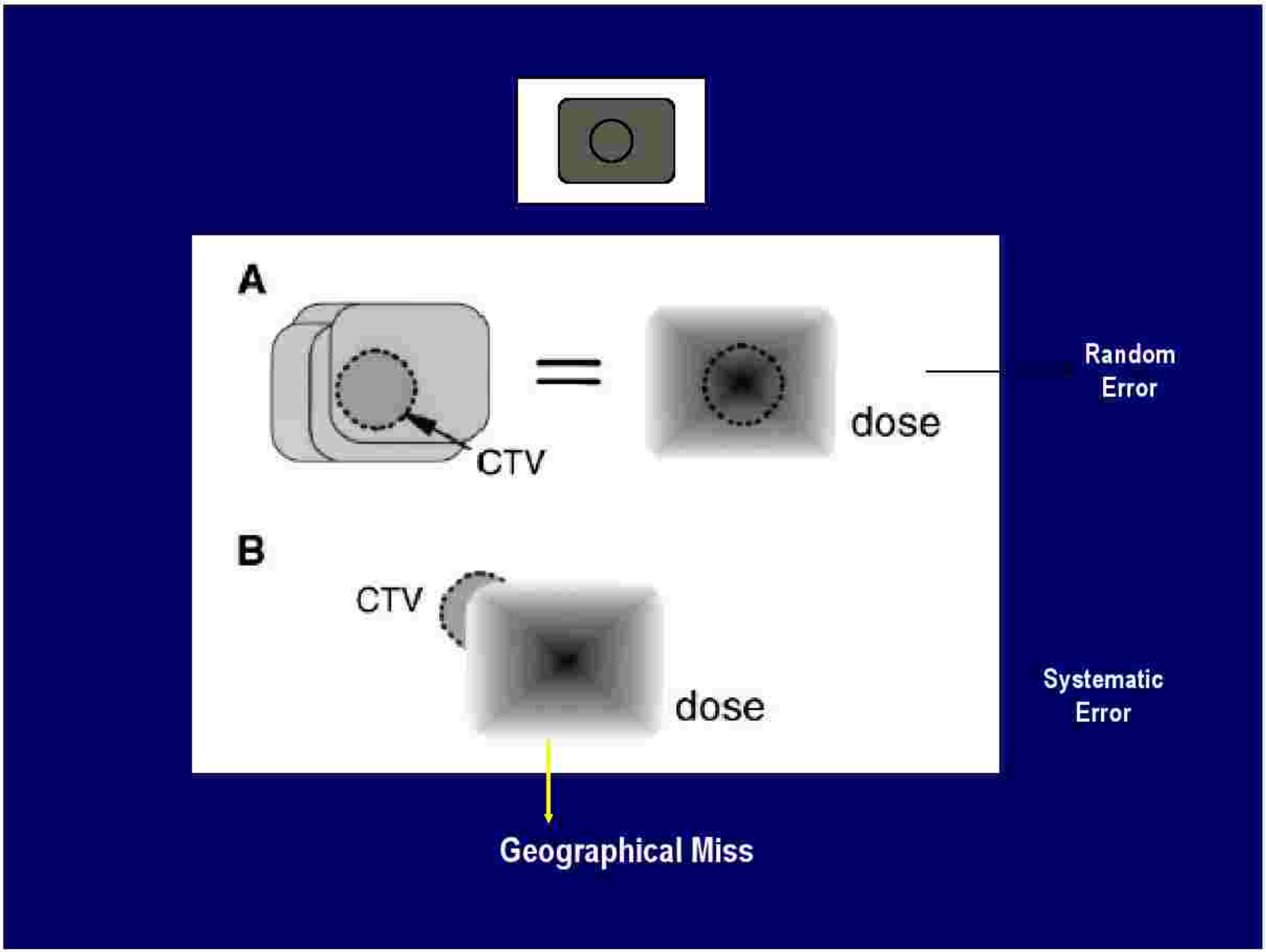
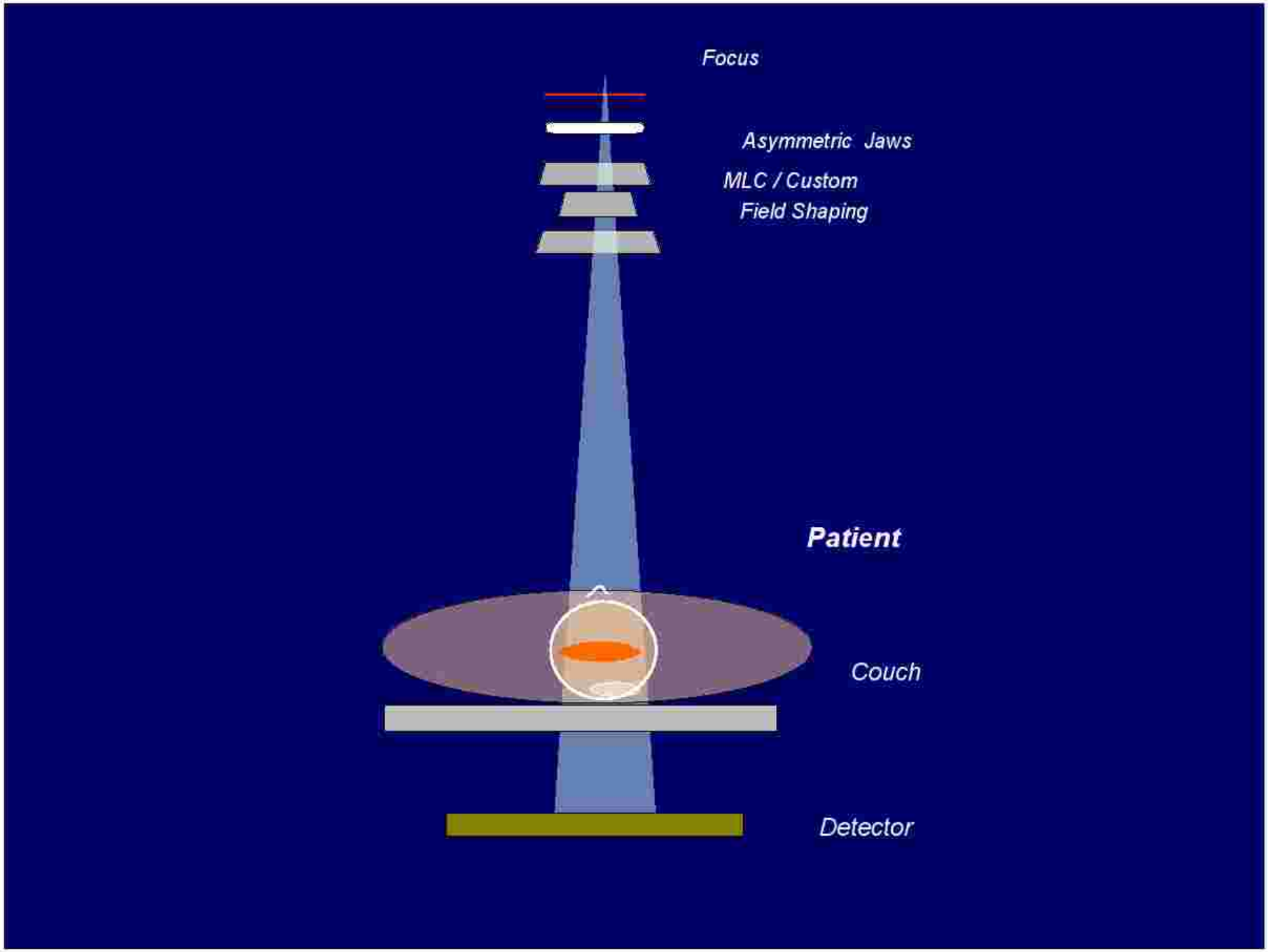


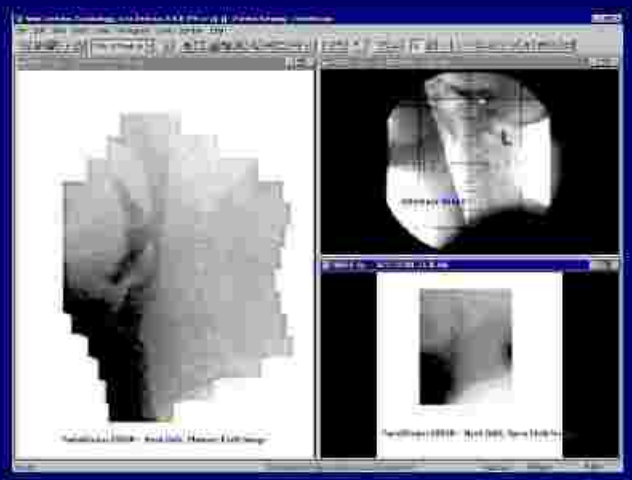
Set up error: is the difference between the intended and actual position of the part of the patient that is irradiated with respect to the treatment beams during the treatment


A
CTV
dose
Random Error
B
CTV
dose
Systematic Error
Geographical Miss


Focus
Asymmetric Jaws
MLC / Custom
Field Shaping
Patient
Couch
Detector

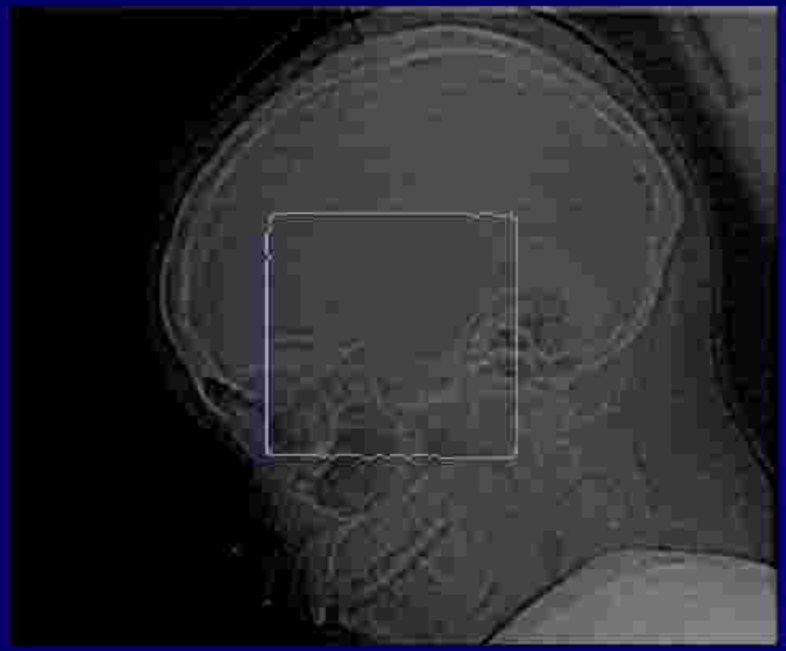
Methods of Treatment verification and Measurement of Errors in Clinical practice

- Film based Portal image
- Electronic Portal Imaging Devices (EPID)
- Ultrasound (BAT)
- CT scan
- IGRT



Portal Image:

Is the image of area being irradiated and is produced with the use of therapeutic X ray beam



Portal Image

- Film based
- Electronic

Aim: To ensure correct patient position during the treatment

Electronic Portal Imaging

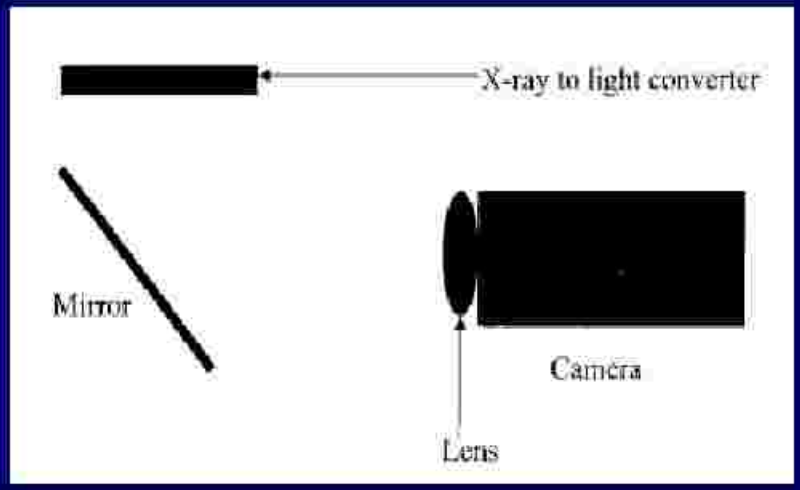
- Images are available immediately
- Images can be used to adjust the field or patient immediately- online correction
- Digital images: can be enhanced by changing contrast and brightness
- Can be used for matching with DRR or with simulator image.

Electronic Portal Imaging Device (EPID)

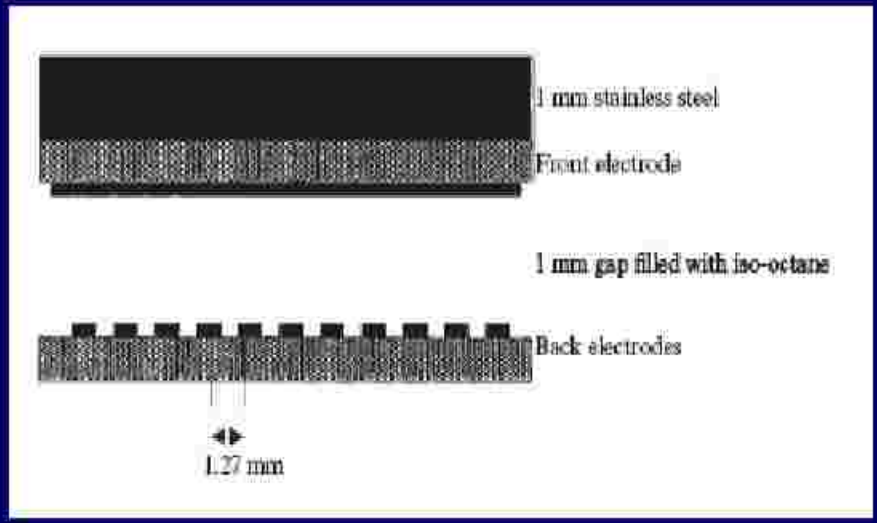
- 1980s…. *Norman Baily*
- Commercial EPIDs in 1990s

Types of EPID

- Liquid ionization chamber based
- Camera based
- Amorphous silicon based

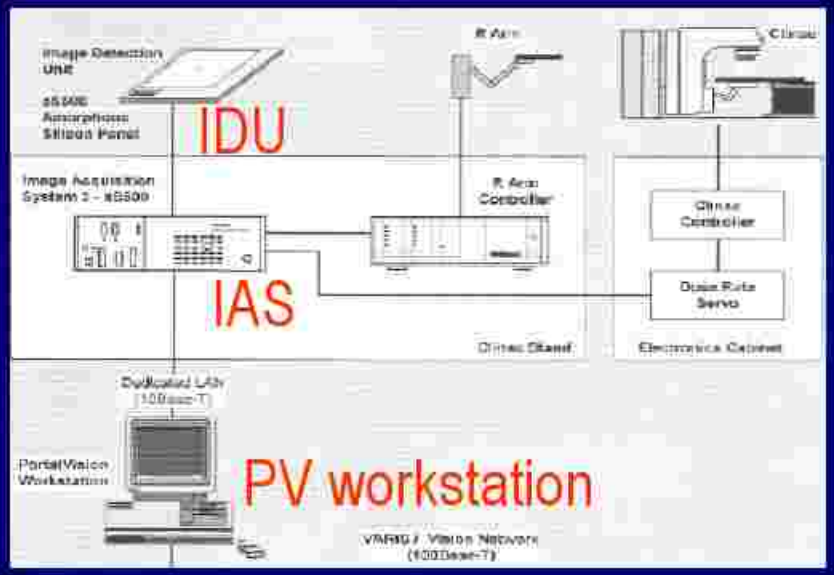


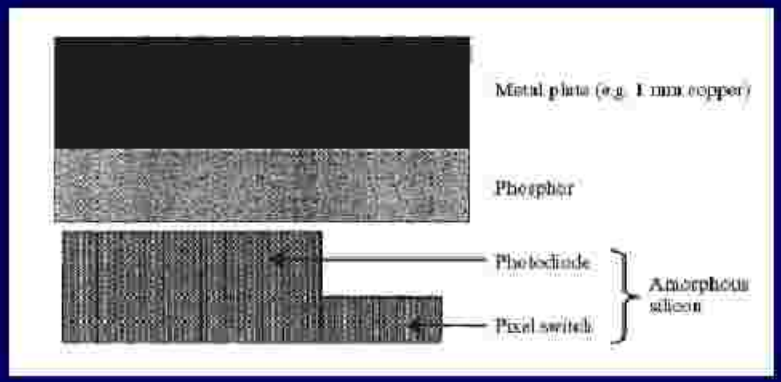
Camera based system



Liquid Ion chamber system

Amorphous Silicon System



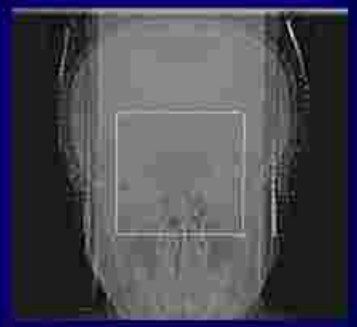


- Image Detection Unit (IDU) :

  featuring the detector and accessory electronics
- Image Acquisition Unit (IAS2) :

  containing drive and acquisition electronics and interfacing hardware
- A dedicated PortalVision workstation

Set-up verification using EPID



Ant - EPID

Lat - EPID

Portal Imaging done: weekly, twice weekly, daily

Images obtained for fixed field sizes 8×8 or 10x10 at isocentre

Anterior and lateral portal images are taken irrespective of the treatment fields

DRR of same field size is obtained from the planning system

Image matching/Registration

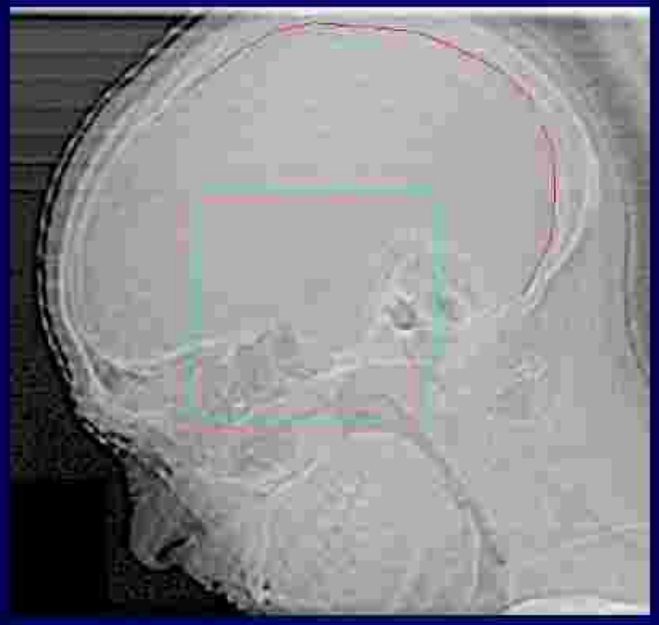
Image Matching

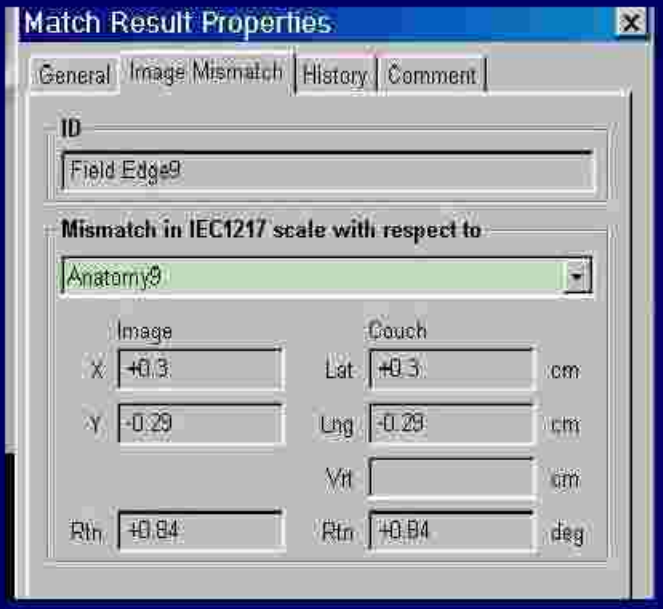
Image during treatment planning —— Image during treatment execution

Reference Image

- DRR
- Simulator Image
- First portal Image

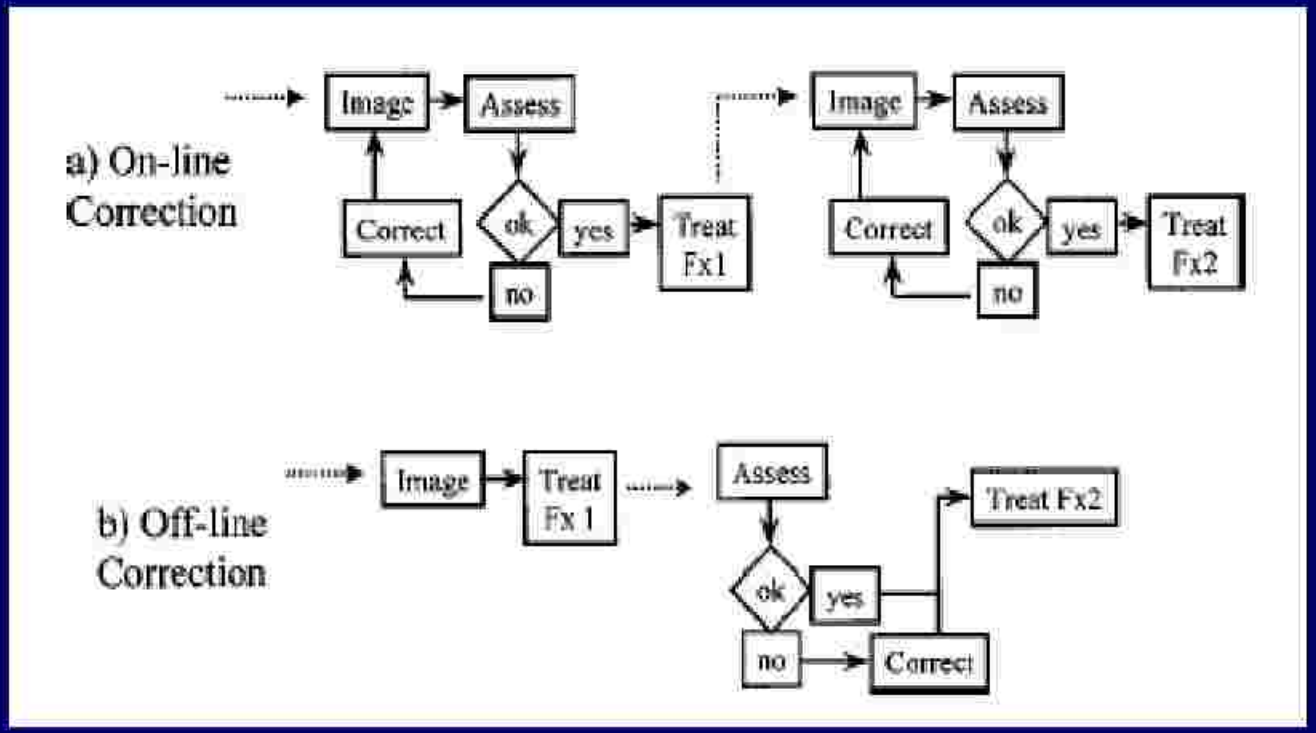
Anatomy matching





Correction Protocol

1. Online correction
2. Offline correction



PTV Margin

- PTV is Planning target volume
- Geometric margin depends upon the margin required for set up errors and organ motion
- PTV = ITV + Set up margin (SM)
- ITV is internal target volume
- Internal Target Volume (ITV) = CTV + Internal margin (IM)

External Motion: Patient Movement; Errors in reproducibility and Daily variations



Set Up Margin: SM

Internal Motion: Breathing, Swallowing, Peristalsis:

Internal Margin: IM-NOT SO IMPORTANT IN BRAIN TUMORS

Set up margin (SM)

- Variations in patient positioning
- Loosening / variation in Immobilisation devices
- Mechanical uncertainty of equipment (sagging of gantry, collimators, couch, lasers)
- Transfer errors from localisation CT scans / simulators to treatment units
- Human factors: training, experience, concentration and time available for technologist
- Patient's physical and mental state

PTV Generation

- Several recipes; the 'Dutch' recipe is most common
- An assessment of the standard deviation of the systematic error (Σ_{setup}) and the standard deviation of the random error (σ_{setup}) is required
- Stroom's formula: CTV to PTV margin

  PTV = $2\Sigma + 0.7\sigma$ o

- Van Herk's formula: CTV to PTV margin

  PTV= $2.5\Sigma + 0.7\sigma$

- These generally guarantee that there is a 90% probability that 99% of the CTV will be encompassed by 95% isodose (assuming that the PTV is encompassed by the 95% isodose!)

Set-Up error in Head & neck region

Film or EPID	No. of patients	No. of images	Direction	σ_{sys} (mm)	σ_{random} (mm)	Ref.
Film	22	193	cc	2.1	2.1	[45]
			ap	2.1	2.1	
EPID	21 (old mask)	470	ml	1.8	1.5	
			cc	1.7	1.8	[5]
			ap	2.0	1.6	
EPID	10 (new mask)	156	ml	1.8	1.5	
			cc	1.7	1.1	
			ap	2.0	1.6	
Film	27	234	cc	4.3	2.5	[63]
			ap	4.6	2	
Film	29	136	ml	2.2	2.1	[103]
			cc	1.8	1.9	
			ap	1.9	2.0	
EPID	26	356	ml	1.8	1.6	[98]
			cc	2.7	1.5	
			ap	1.7	1.2	
			rot ap	1.2°	0.8°	
			rot ml	0.7°	1.0°	
Film (85%); EPID (15%)	43	515	cc (Orfit)	3.4	2.1	[101]
			ap (Orfit)	3.4	2.1	
			cc (PVC)	3.6	2.1	
			ap (PVC)	3.6	2.1	
EPID	12	192	cc	2.0	1.4	[104]
			ap	1.3	1.7	
EPID	12	290	ml	1.8[b]	1.4	[32]
			cc	2.2[b]	1.4	
			ap	1.7[b]	1.4	

Hurkmans C W et al. Radiotherapy and Oncology 58,2001

Immobilisation for Stereotactic irradiation

Systematic errors

Direction $N = 15$	Mean	1 SD
Anterior portal		
Medial/lateral (mm)	0.8	0.7
Cranial/caudal (mm)	0.8	0.8
Rotation in coronal plane (°)	0.0	0.3
Lateral portal		
Anterior/posterior (mm)	−0.1	0.9
Cranial/caudal (mm)	0.0	1.0
Rotation in sagittal plane (°)	0.0	0.5

Random errors

Direction	1 SD
Anterior portal (126 images)	
Medial/lateral (mm)	0.6
Cranial/caudal (mm)	0.6
Rotation in coronal plane (°)	0.5
Lateral portal (123 images)	
Anterior/posterior (mm)	0.6
Cranial/caudal (mm)	0.7
Rotation in sagittal plane (°)	0.5

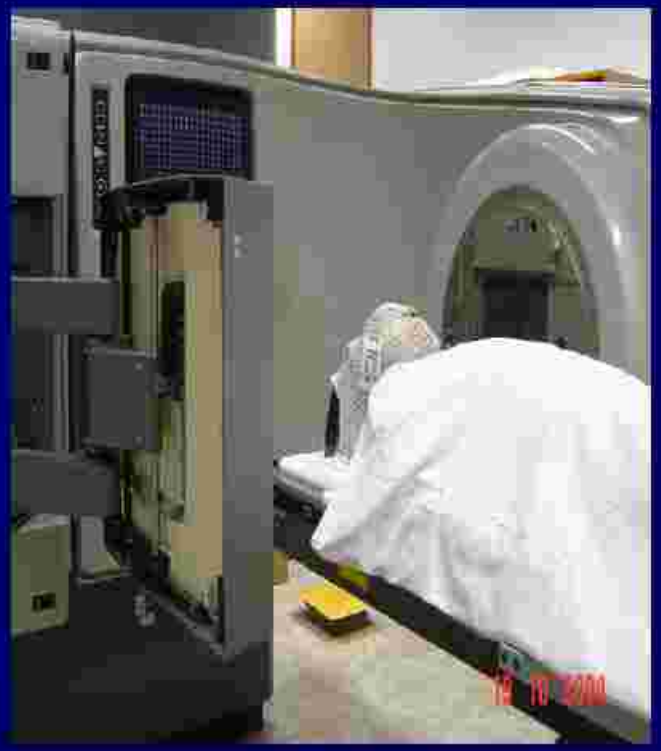
Kumar Radioth & Oncol 2005; 74:53-59

BrainLAB Relocatable mask/frame

Comparison between simulator film and repeat simulator films	Mean	SD
Anterior film		
medial / lateral	0.0	0.8
cranial / caudal	0.4	1.4
rotation in coronal plane	0.1	1.2
Lateral film		
anterior /posterior	0.0	0.8
cranial / caudal	0.5	1.7
rotation in sagittal plane	0.4	1.5
3-D displacement	2.1	1.2

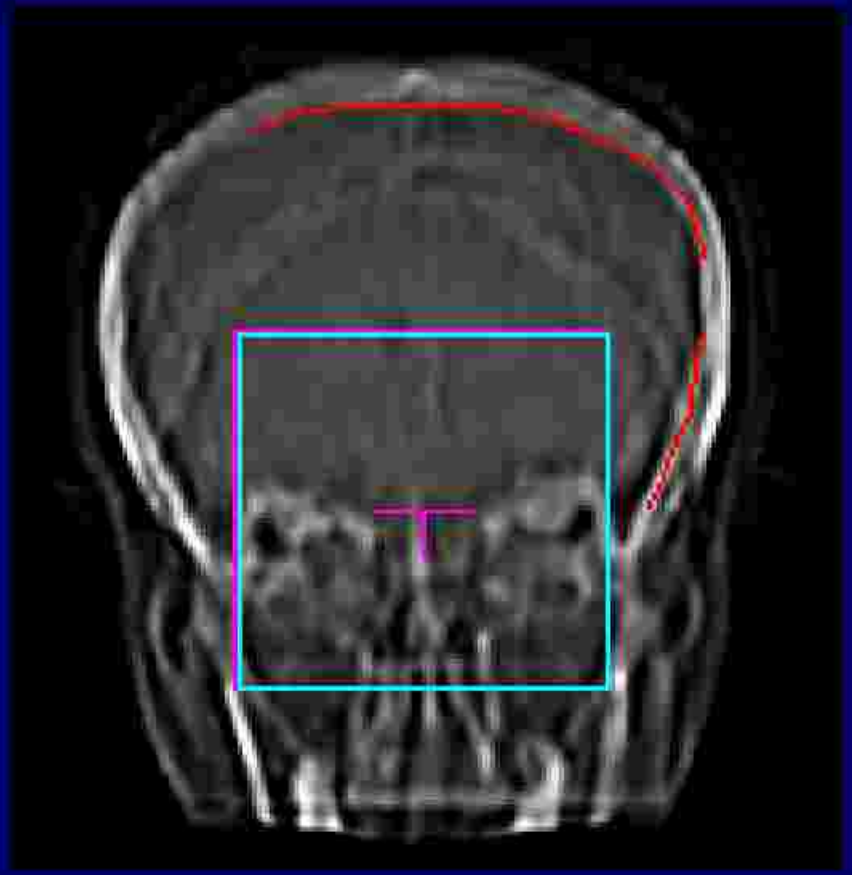
Alheit Strahlentherapie Oncologica 2001

TMH EPID study for margin generation

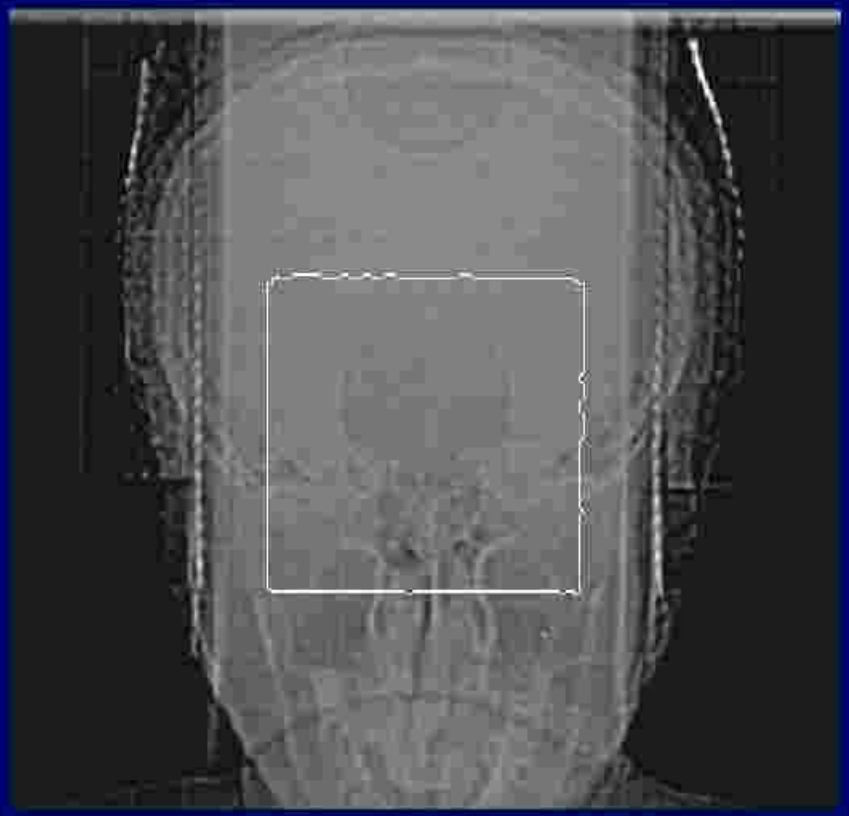


- Portal Vision: Amorphous silicon detector aS500 attached Varian 6 EX with retractable arm
- Anterior and lateral portal images of 8×8 Field size
- Portal Imaging done twice weekly

Anterior DRR

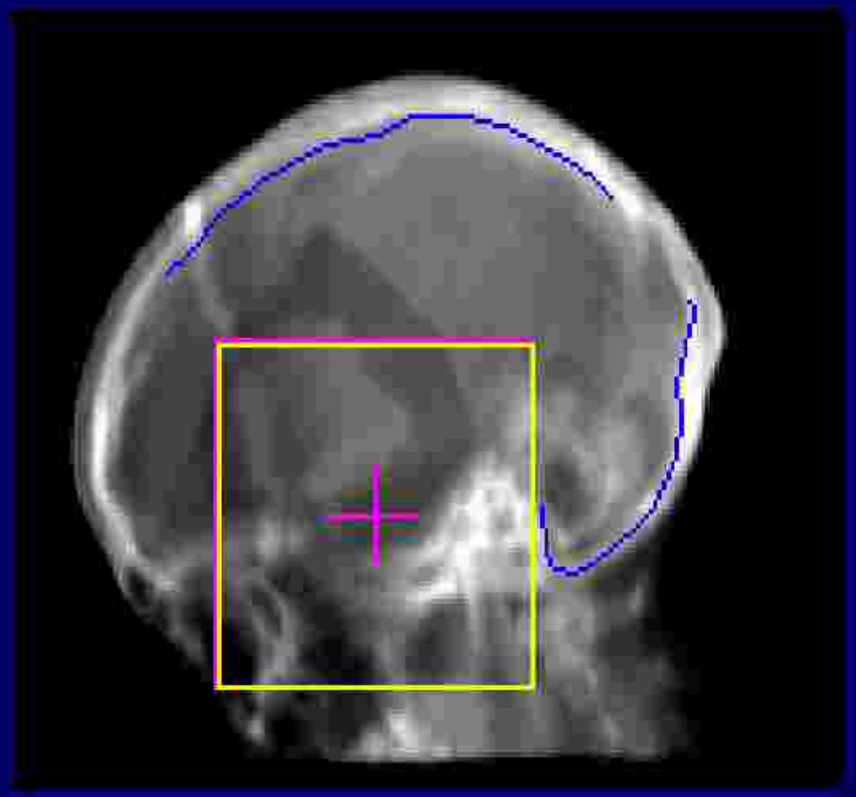


Anterior Portal image

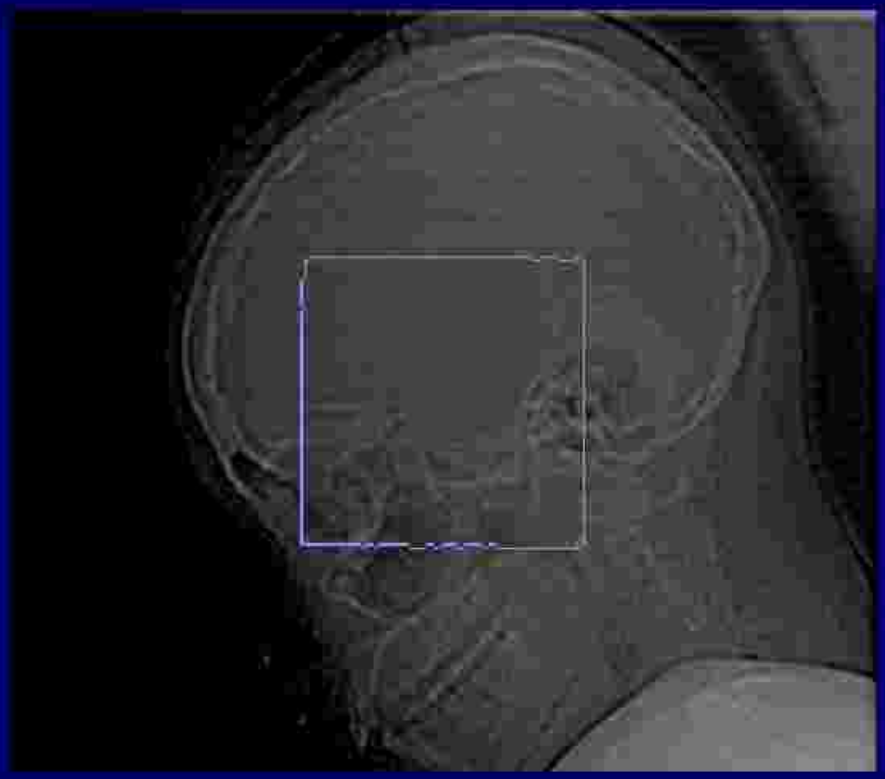


Total number of Images in 15 patients : 130

Lateral DRR

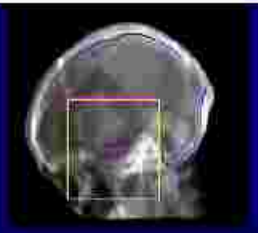


Lateral EPID Image



Total number of Images in 15 patients : 128

	Systematic Errors	Random Errors
Direction	1 Standard Deviation	1 Standard Deviation
Anterior Portal		
Medial/Lateral (mm)	1.8	1.2
Cranial/Caudal (mm)	2.0	1.6
Rotation in coronal plane (°)	0.91	0.97
Lateral Portal		
Anterior/Posterior (mm)	2.1	1.5
Cranial/Caudal (mm)	2.0	2.0
Rotation in sagittal plane(°)	1.42	1.45



Total Errors

Direction	Mean mm	1 Standard Deviation
Anterior Portal (130 images)		
Medial/Lateral (mm)	1.233	2.0
Cranial/Caudal (mm)	-0.8	2.6
Rotation in coronal plane (°)	0.41	1.24
Lateral Portal (128 images)		
Anterior/Posterior (mm)	**4.8**	2.4
Cranial/Caudal (mm)	-0.9	2.8
Rotation in saggital plane(°)	0.65	2.04

Margin Generation Protocol

Generation of CTV to PTV margin Stroom IJROBP 1999 :

PTV= 2 × Systematic Error + 0.7 × Random Error

Direction	Formula	Margin (mm)
Medial/Lateral	2 x 1.8 + 0.7x .2	4.4
Cranial/Caudal	2 x 2 + 0.7x1.6	5.12
Anterior/Posterior	2 x 2.1+ 0.7x1.2	5.25

*

Summary

- Treatment verification using portal imaging is important especially for high precision techniques
- Electronic Portal Imaging is the current standard
- Accurate immobilization
- Each institution should develop their own for portal vision and QA
- Margin for PTV should ideally be derived from your own data.