Patient immobilization and setup verification

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The Problems:

- The correct dose of radiation shall be delivered just to the target.
- The dose to surrounding structures shall be as low as possible.
- Must be achieved on many occasions (typically >30 treatment fractions)
- It must be verifiable
- Must be documented in a way that allows others to understand all important factors of the treatment performed

Contents of lecture

1. Sources of uncertainty
2. Methods to verify dose delivery
   - portal films / EPID’s
   - in vivo dosimetry
3. Customization of the blocks
4. Patient positioning and immobilization devices

1. Sources of uncertainty

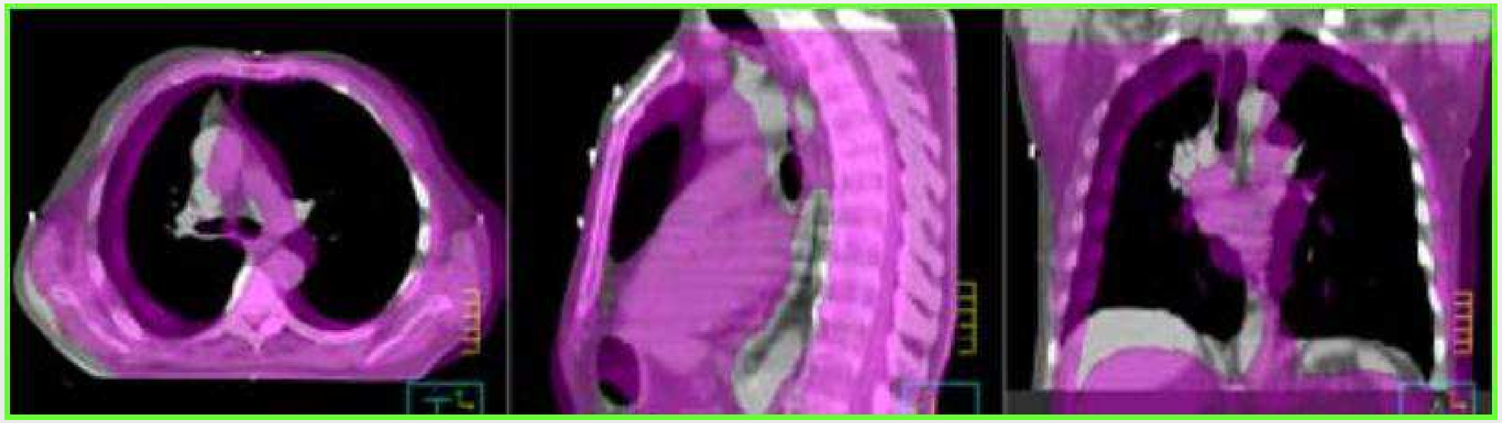
- Patient localization
- Organ motion
- Imaging (resolution, distortions,…)
- Definition of anatomy (outlines,…)
- Beam geometry
- Dose calculation
- Dose display and plan evaluation
- Plan implementation

Patient localization

- The patient should be positioned identically during diagnostics (CT), in simulation and 30+ times during treatment
- Sources of uncertainty:
  - motion
  - reliability of marks on the skin
  - couch sag

Organ motion

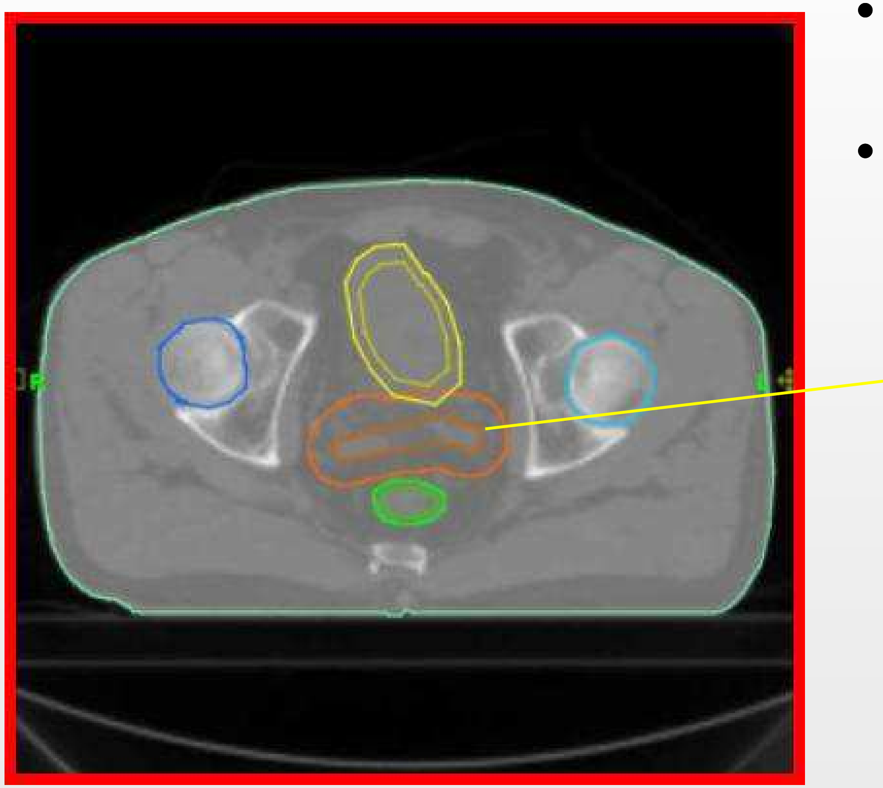
- Affects most organs - particularly noticeable for lung cancer, liver, prostate and other pelvic malignancies
- Shown here is the difference in CT scan between inhale and exhale position



Imaging issues

- Partial volume effects
- Distortion (MR)
- Limited spatial resolution (PET)
- More discussion on these issues in the companion course on diagnostic radiology

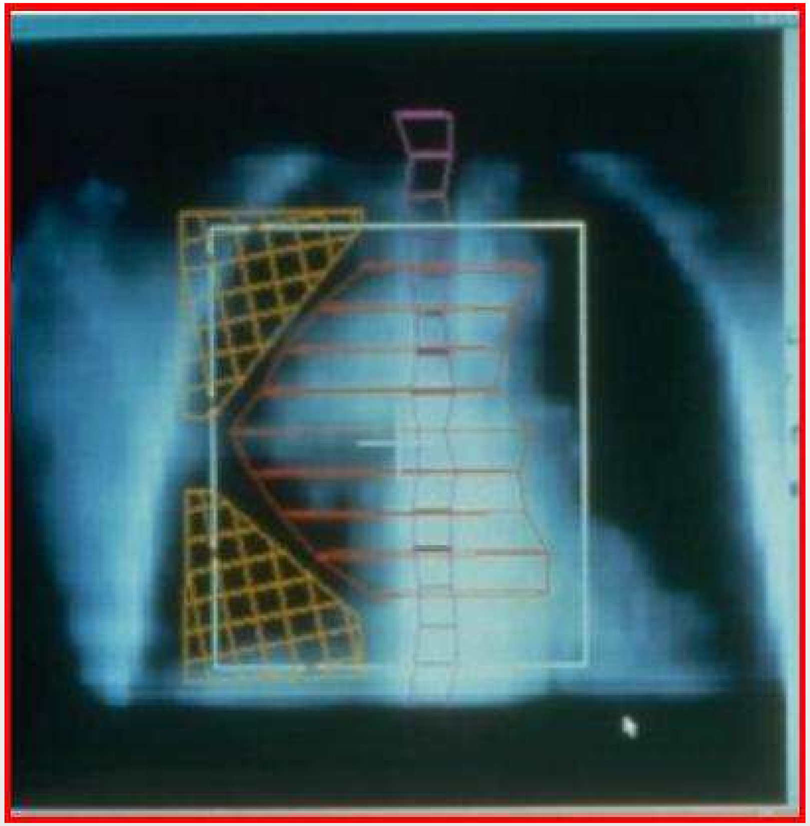
Target definition, outlining of organs



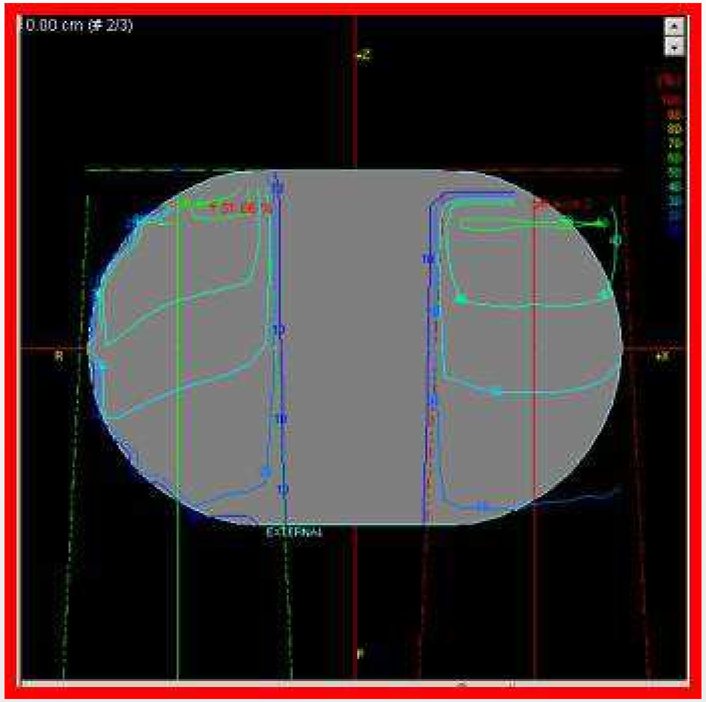
- Decide where the organ is and what extend it has.
- Are the seminal vesicles really where they are drawn here?

Beam geometry and positioning

- Is the block exactly where it should be?
- Is there gantry sag?



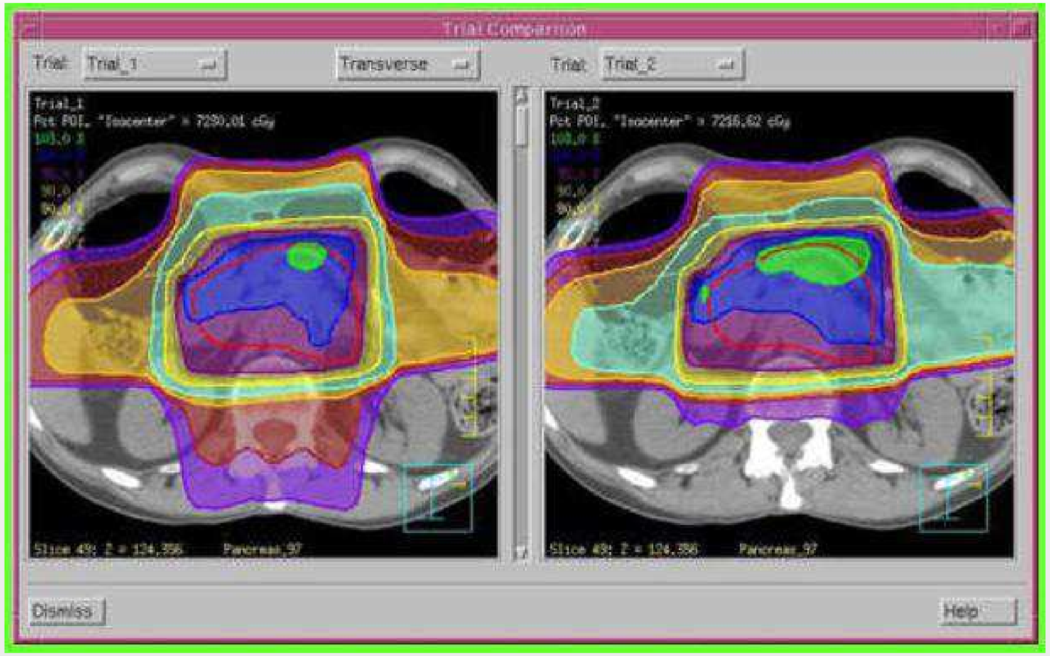
Dose calculation



- There are many different dose calculation algorithms
- All have limitations (and be it the long time required to calculate the dose)
- Must know what to trust

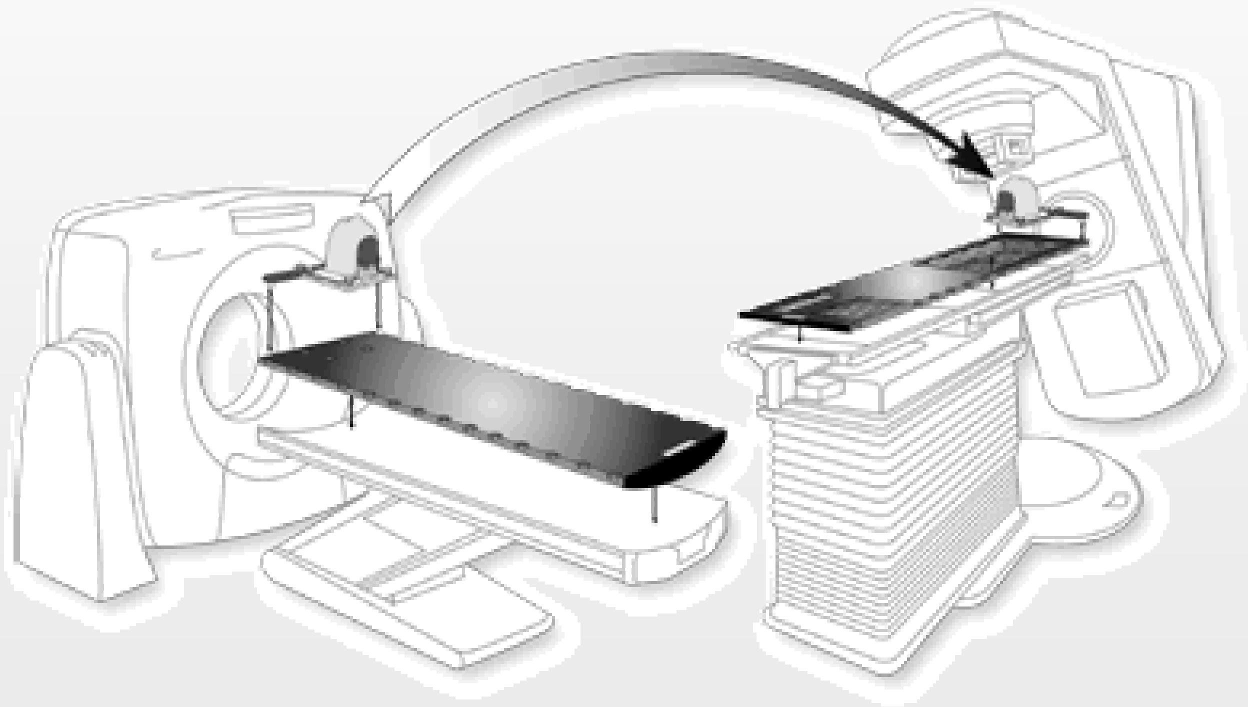
Plan display and evaluation

- Comparison of competing plans...



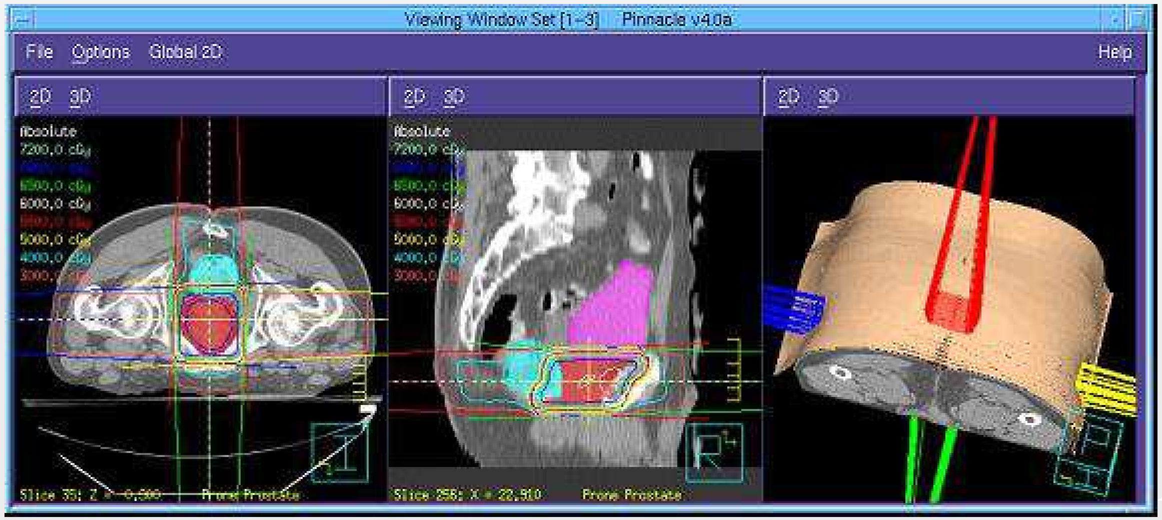
Implementation of the plan

- Transfer of data between units



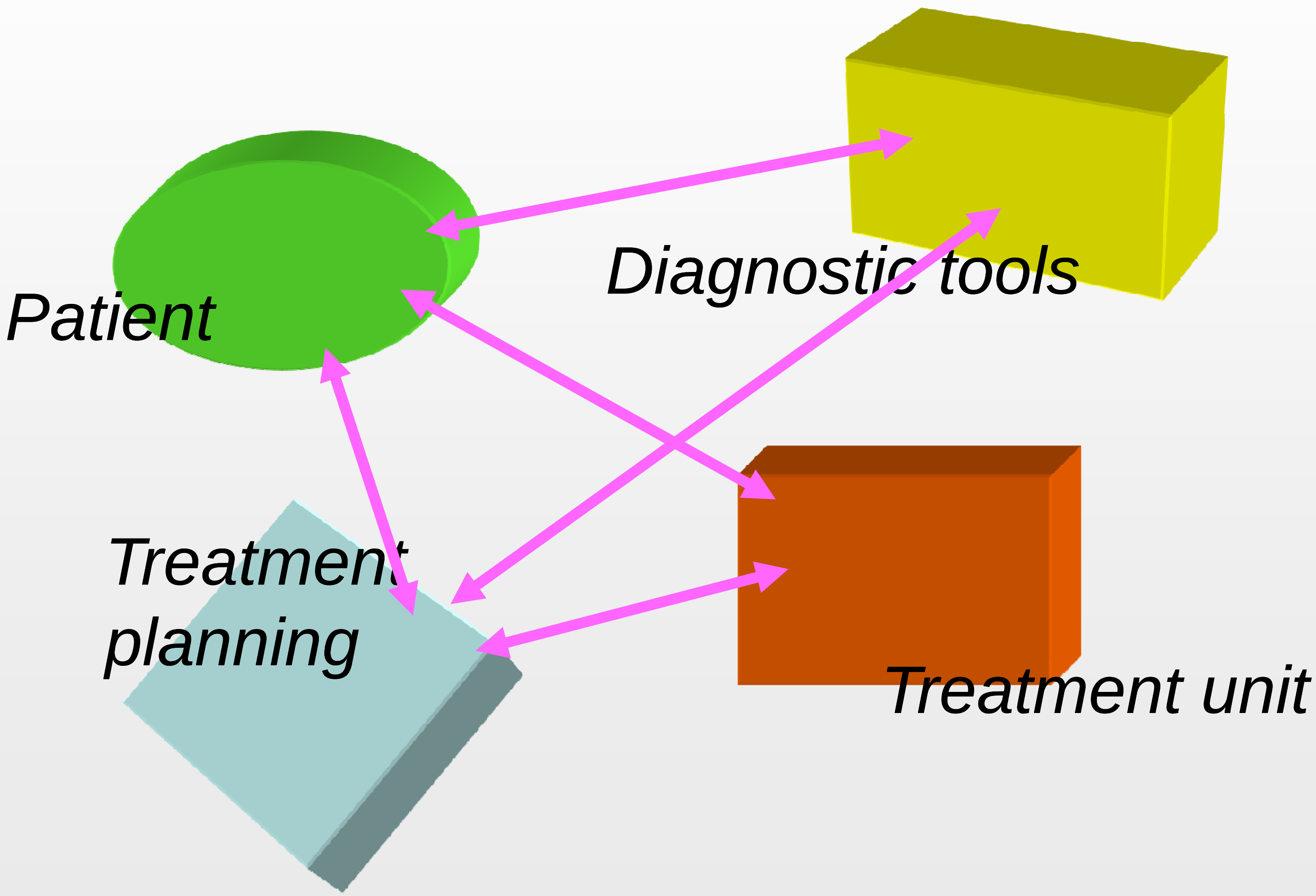
2. Verification of dose delivery

- The plan looks great...
- However, one must ensure that during treatment everything is matching the treatment plan



ADAC

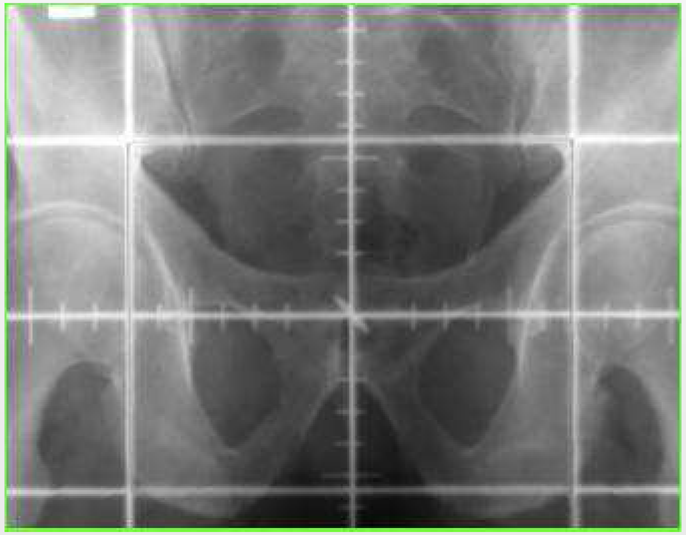
In practice there are many systems, ensure different co-ordinate systems match...

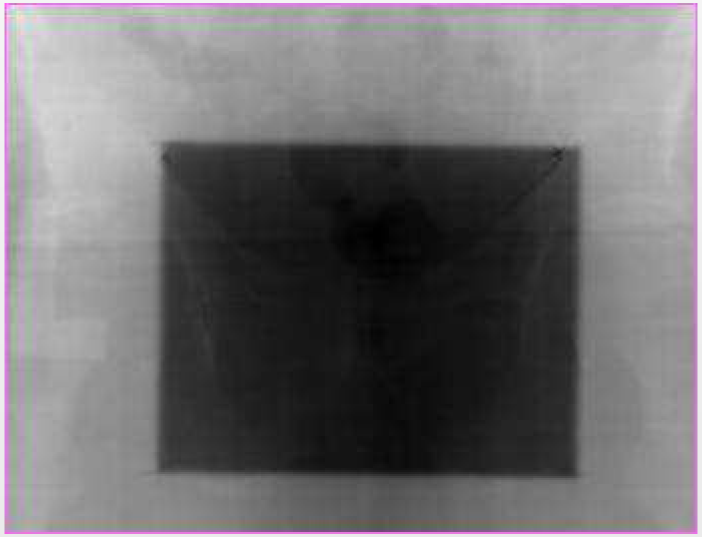


Most important comparison

- Reference from planning
  - Simulator film
  - DRR

- Check film during treatment
  - Port film
  - EPID



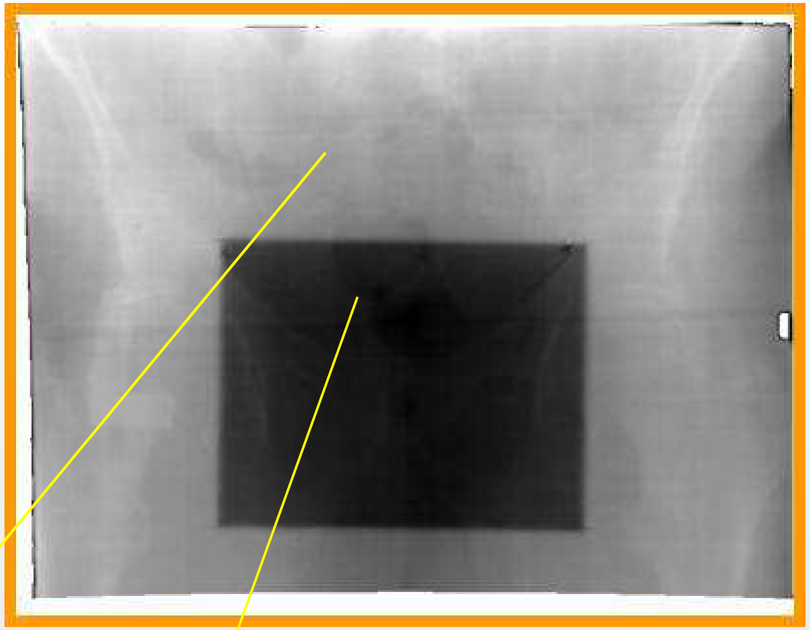


Portal films

- Taken during (or directly before) treatment with:
  - beam from the treatment unit
  - patient in treatment position
  - shielding in place

Port films

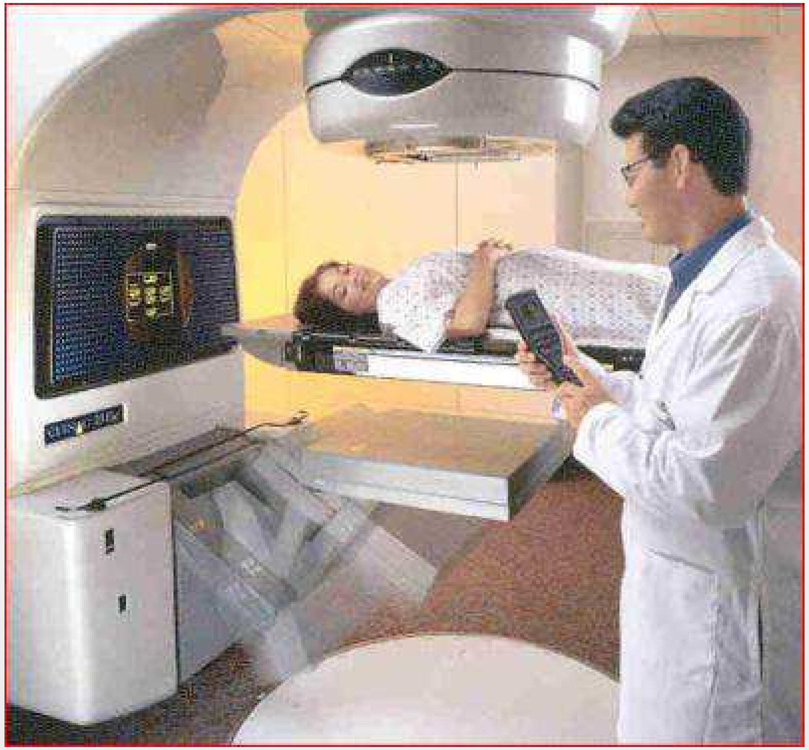
- Usually taken before or after treatment
- If the field itself does not show enough anatomy, a double exposure technique can be used:



Expose treatment field
Open collimators and expose the same film again

Electronic Portal Images

- A film less way to verify field location
- Mounted on the linac
- Different systems:
  - ion chamber
  - fluoroscopic screen
  - semiconductor arrays



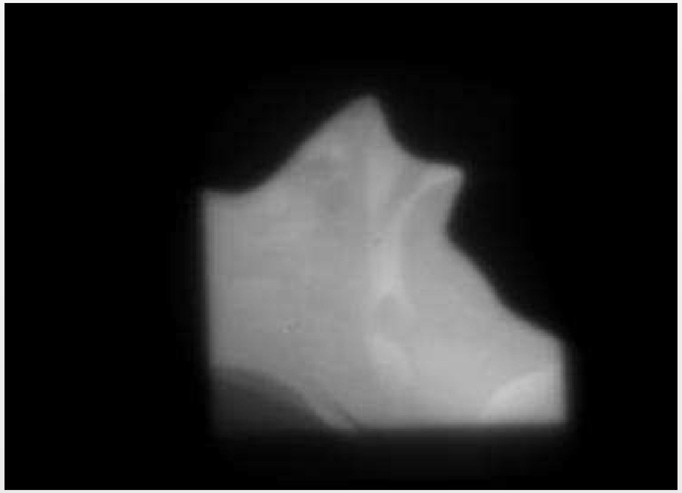
Electronic Portal Imaging Devices - EPIDs

- Offered by all major manufacturers
- Has several advantages:

- Easy use and positioning of the system
- Allows on line verification
- Multiple images (‘cine’) can be taken during one treatment
- Images available in digital format

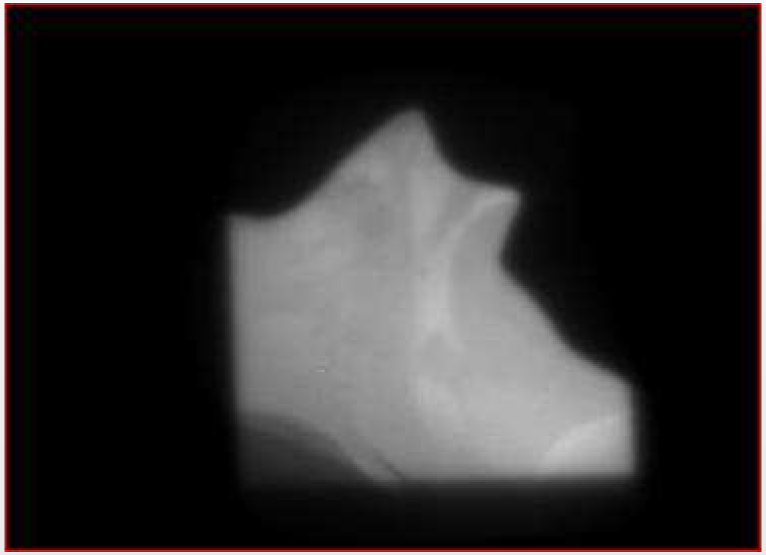
Verification films/images

- Two different aims:
  - verify correct shielding
  - verify patient location



Verify block shape and position

- Should be done for **every** treatment field at least once per course of radiotherapy.



Verify patient location

- Should be done using two images which give adequate information on the location of the target in respect to the treatment beam geometry.
- These do not necessarily need to be treatment fields (example: in case of IMRT or arcs)
- This verification should be repeated every week during treatment for radical treatments

Verify dose delivered to the patient

- May be done in customized anthropomorphic phantoms
- More likely using *in vivo* dosimetry

Breasts modeled on a particular patient to verify skin dose using TLDs.

In vivo dosimetry

ICRU report 24 (1976):

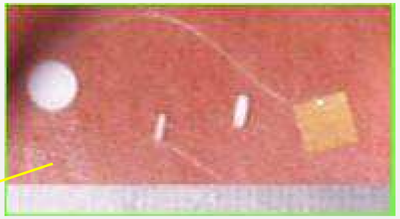
“An ultimate check of the actual treatment given can only be made by using *in vivo* dosimetry.”

Why do in vivo dosimetry

- Quality Assurance – Treatment Verification
- Measure because we don't know
  - limitations of dose planning
  - patient movement
- Verify dose for the record
  - critical organs
  - legal aspects
  - clinical trials

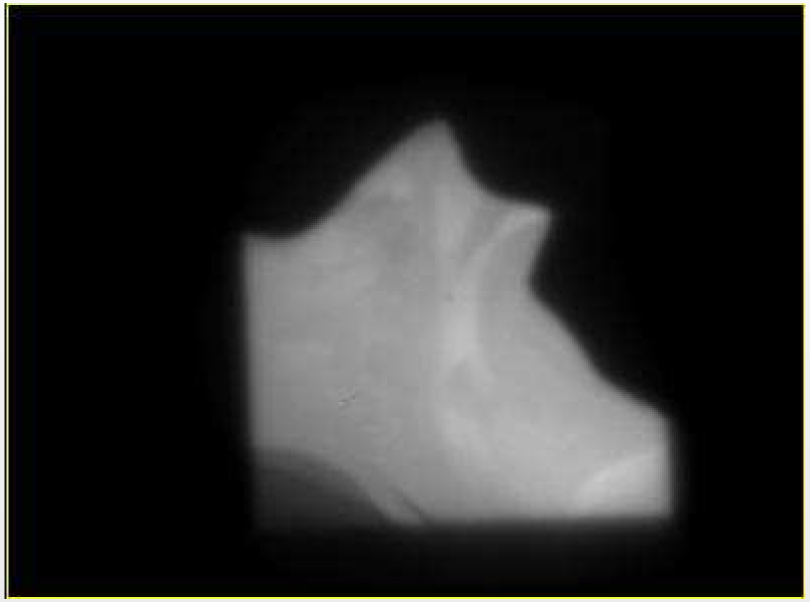
Potential detectors

- Needed: High sensitivity, tissue equivalence, high spatial resolution



- TLD
- Semiconductors (diodes, MOSFETs)
- Radiochromic film
- Others (alanine, gel dosimetry, …)

In vivo exit dosimetry



- Calculate exit fluence
- Determine what the portfilm/EPID should look like
- Verify dose by projecting back

Planning Target Volume (PTV)

- Tissue volume that contains a CTV plus a margin to account for variations in treatment delivery, including variations in
  - treatment set-up
  - patient motion during treatment
  - organ motion
- PTV is a static, geometric concept

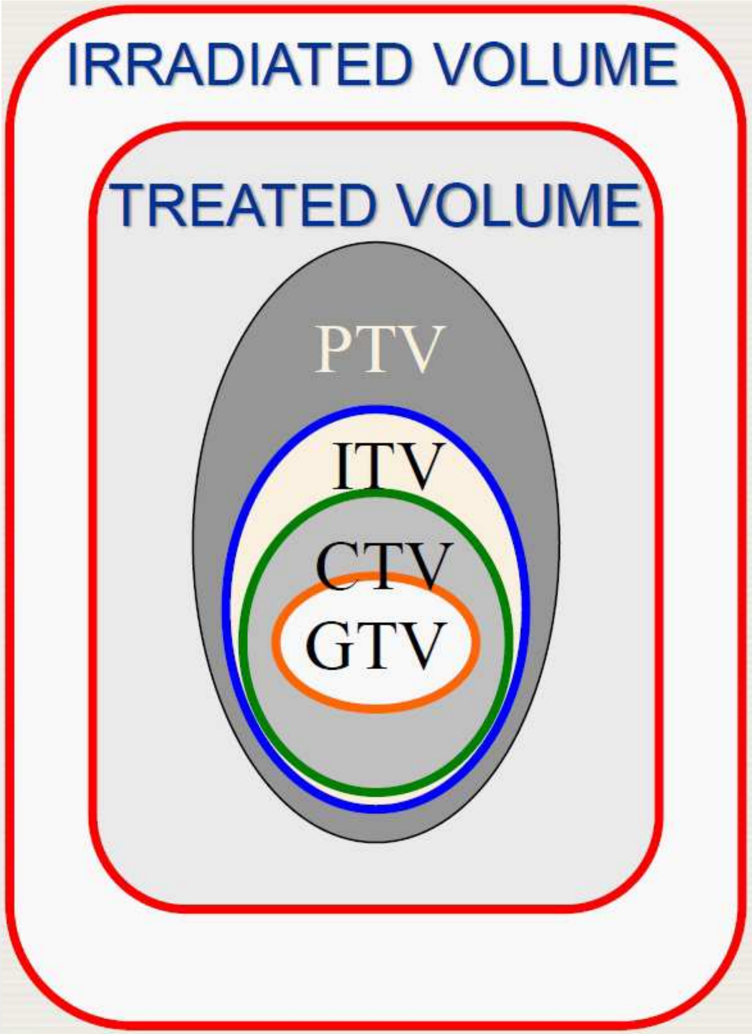
Planning Target Volume (PTV)

- PTV depends on the precision of tools
  - immobilization devices
  - lasers
- PTV does NOT include margin for dosimetric characteristics beam
  - these will require additional margin during treatment planning and shielding design
    - penumbral areas
    - build-up region

Reducing margins

- “Technical” margins can be reduced by improving daily setup.
  - Daily setup verification by EPID, CBCT, ultrasounds…
  - Automatic repositioning of patients by external systems (eg, ExacTrac®).
  - Automatic repositioning with internal fiducials (eg, Calypso®).
  - …

Note ...



We may be able to reduce technical margins ...
but not biological margins

- A small reduction of the margin can have a significant effect on the volume of normal tissues that are exposed
- The ability to limit the volume of normal tissue in some instances may allow higher doses to be delivered in the target, thus increasing the probability of local tumor control. However, verification, patient positioning, precision and effective immobilization techniques are essential.

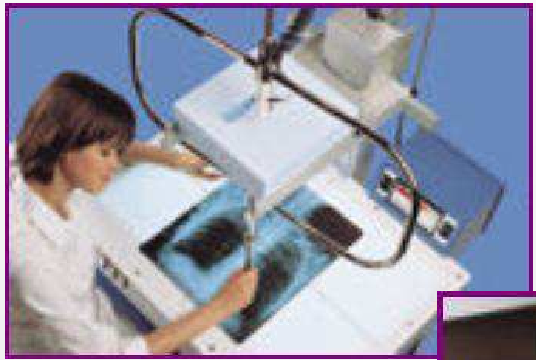
3. Customization of blocks

- Shielding of areas which shall not be irradiated
- Use of blocks - best customized for each individual patient

Customization of blocks

Huestis

- Use block outline on simulator film to cut the block shape into a Styrofoam block

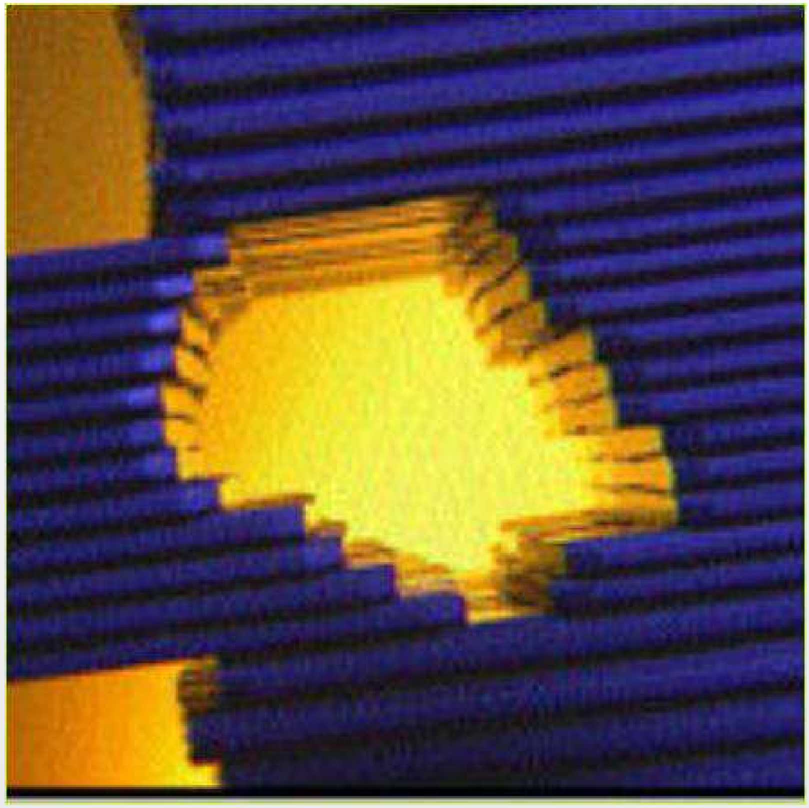


Customization of blocks

- Pour low melting alloy into foam
- Customized blocks include divergence of the beam
- Blocks are mounted on trays

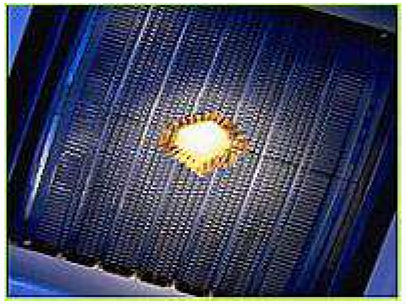
Conformal radiotherapy

- Conform the treated volume (receiving a therapeutic dose) to the planning target volume
- Shield all areas surrounding it
- MLC is an option for this



Blocks versus MLC

- Blocks
  - More work
  - Lifting of heavy blocks required
  - No leakage
  - Divergence covered
  - Isolated blocks (example: larynx shield) possible

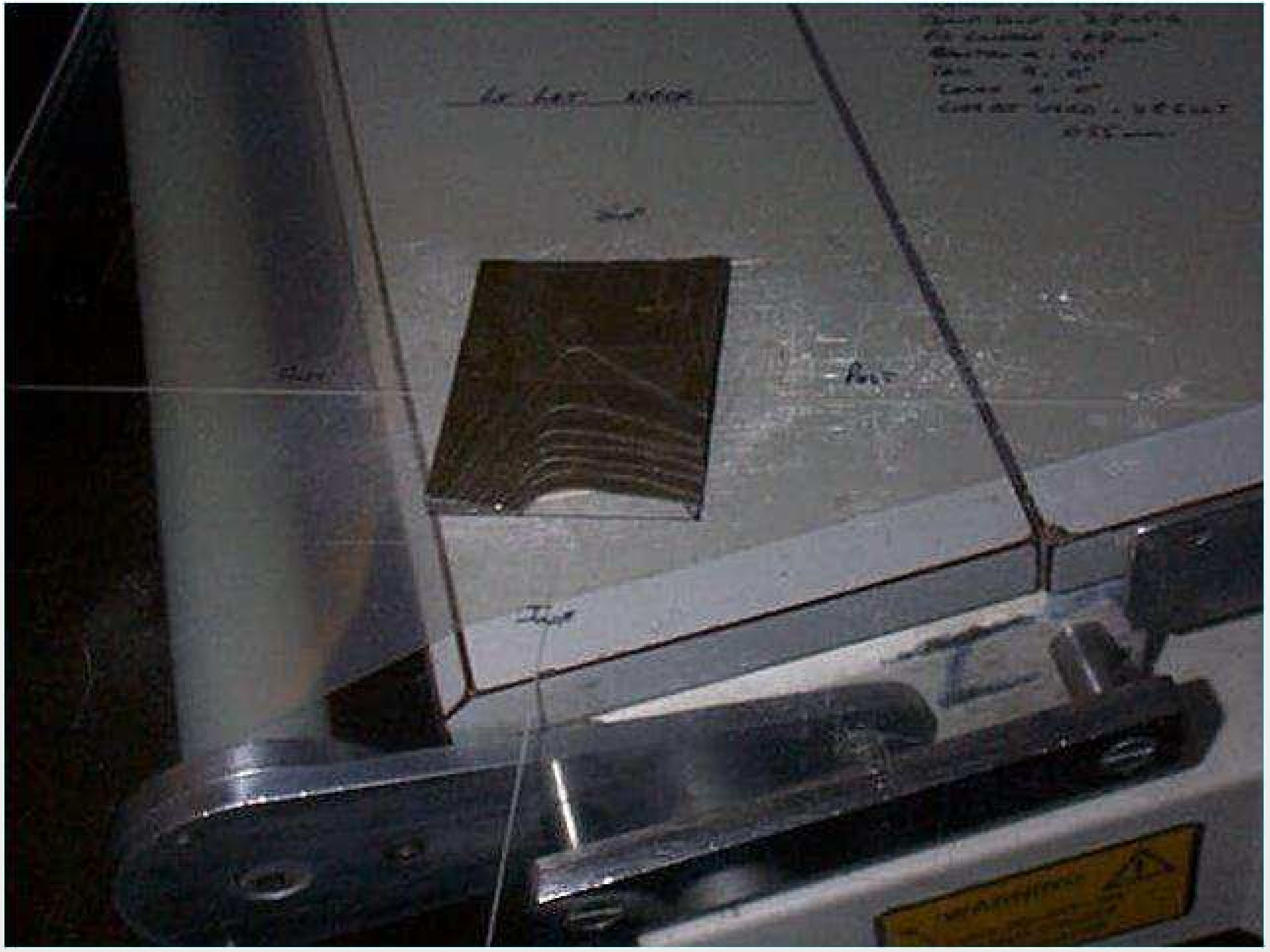


- MLC
  - Interleaf leakage needs to be considered
- Flexible
  - Dynamic shielding possible
  - Required for most IMRT
  - High initial investment, no additional cost per patient

Intensity modulation

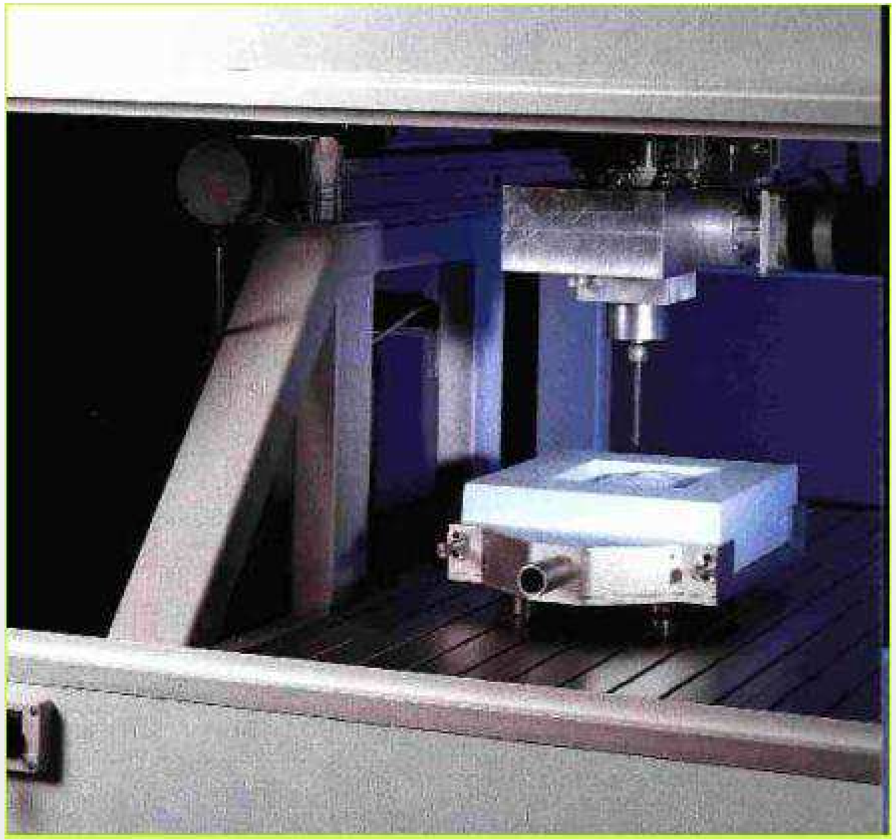
- Optimize the dose distribution
- Make dose in the target homogenous
- Minimize dose out of the target
- Different techniques
  - physical compensators
  - intensity modulation using multileaf collimators

Physical compensator



Compensator manufacturing

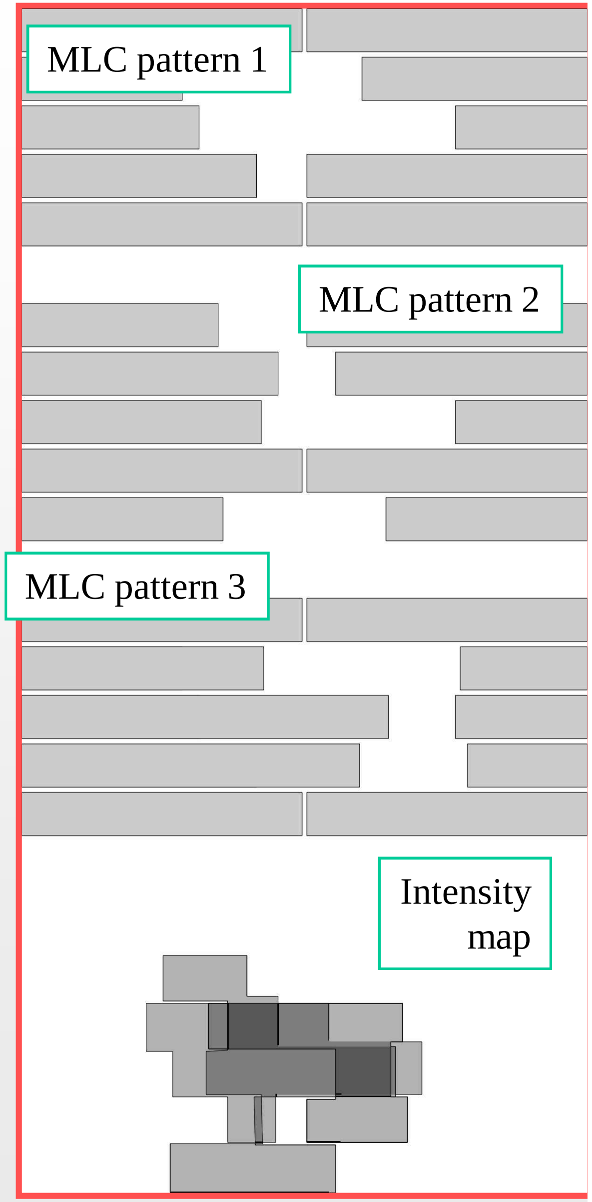
- Sheets of lead glued together (compare previous slide)
- Automatic milling into foam - this can be filled with low melting alloy or steel shot



Par Scientific

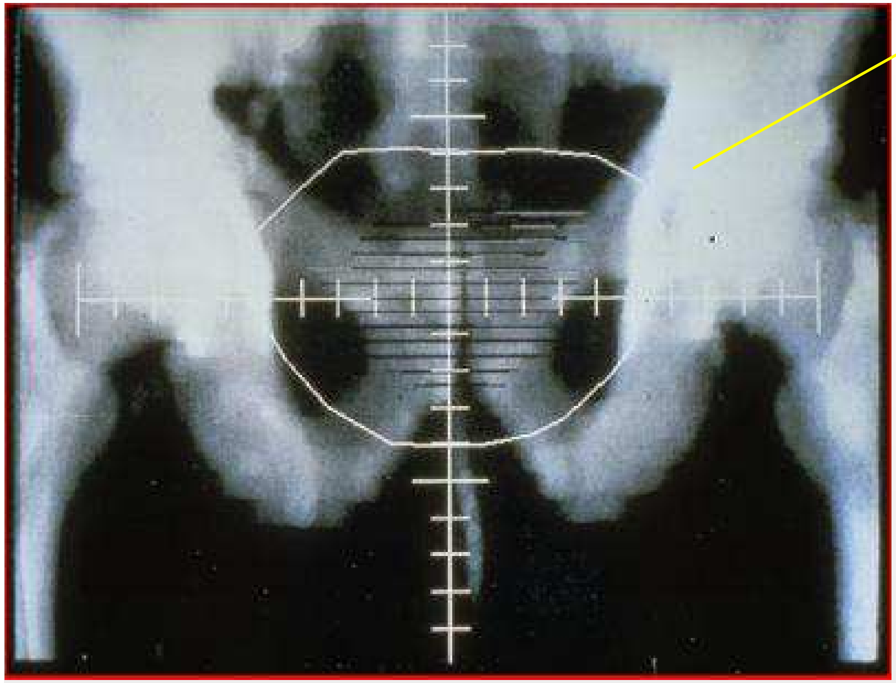
Intensity modulation

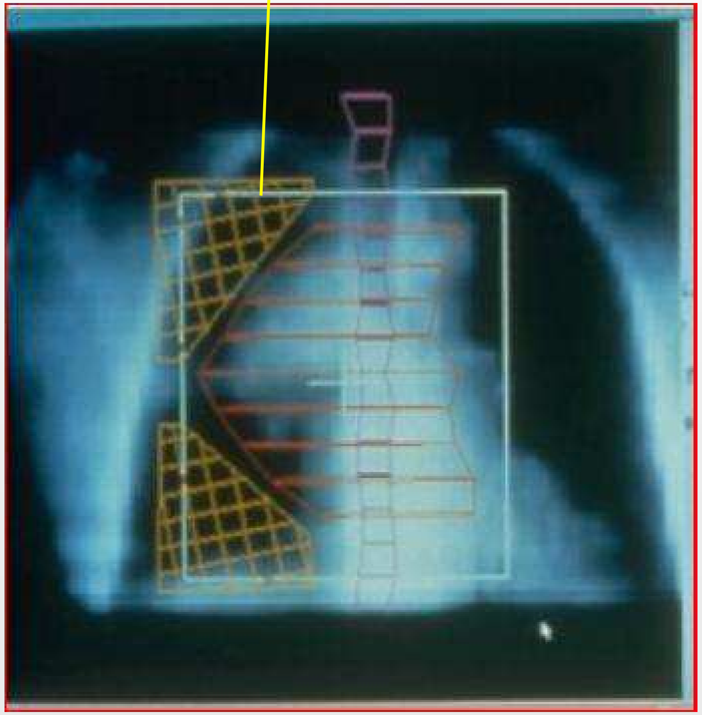
- Achieved using a Multi Leaf Collimator (MLC)
- The field shape can be altered
  - either step-by-step or
  - dynamically while dose is delivered



Collimation

Customized blocks
or prefabricated blocks
in geometric shapes

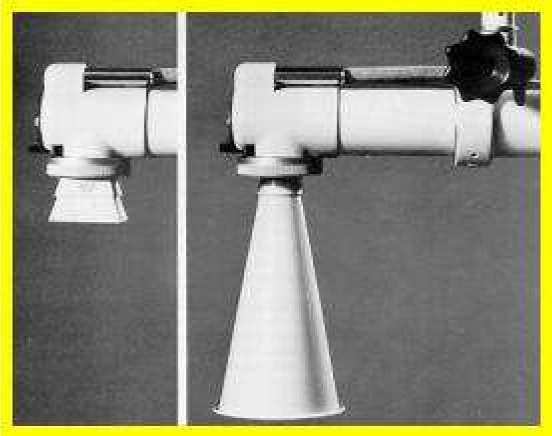




- Aim to limit field to the target only

Collimation

- Applicators
  - electron beams
  - superficial beams
- Movable jaws
- Lead blocks
  - fixed shapes
  - customized
- Multileaf collimator



4. Patient positioning and immobilization devices

- The best collimation does not help if the patient is not stable
  - need good immobilization devices
  - need to put patient in a reasonably comfortable position (this is often difficult with very sick patients)
  - need to make them feel comfortable

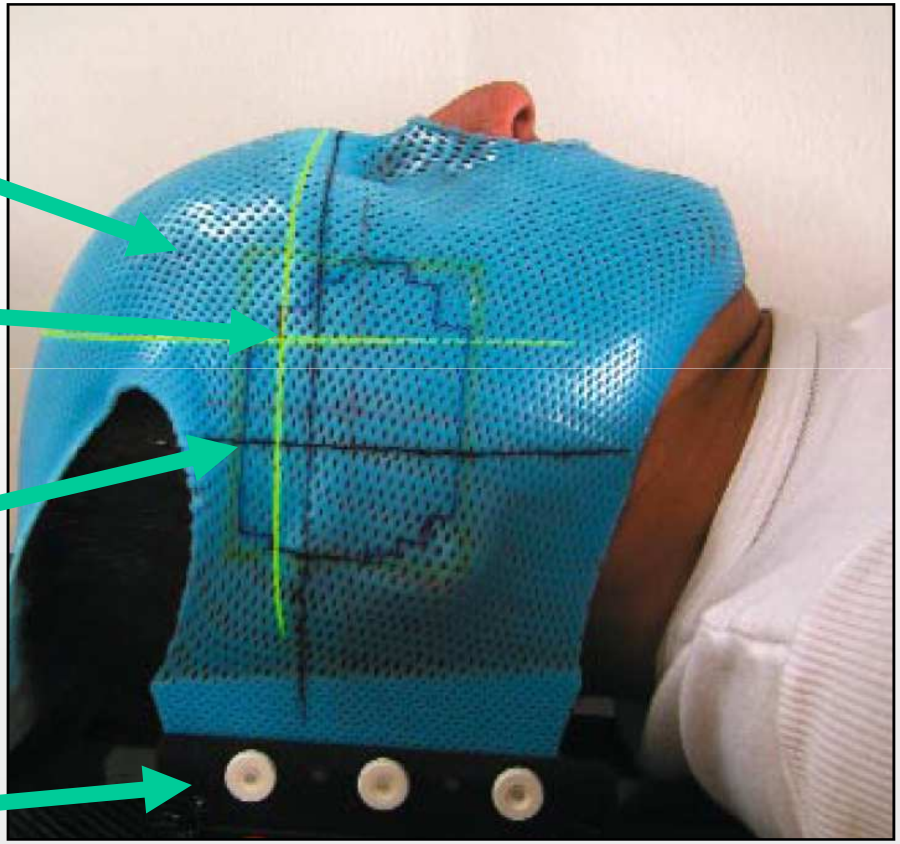
Patient-positioning
A possible solution of the problem

Immobilization: mask

Related to the radiation field

Marking of the target volume on the surface

Reproducibility: fixing the mask to the base



Role of immobilization

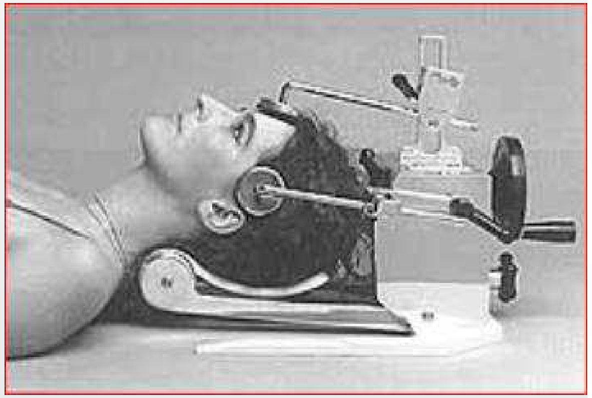
- Patient positioning and immobilization are the most important parts of RT treatment.
- Goal of immobilization systems is to limit patient motion and reduce the probability of major positioning errors
- With out proper immobilization, unwanted side effects
- Immobilization such as molds, casts, headrests, and other devices are constructed to reduce setup error and patient movement during treatment.

Role of immobilization

- A well contructed immobilizing system can reduce the time for daily patient set up.
- Make the patient feed more secure and less apprehesive.
- Reduce the reliance on patient co-operation and alertness, and it can help to stabilize the relationship between external skin marks and internal structures.

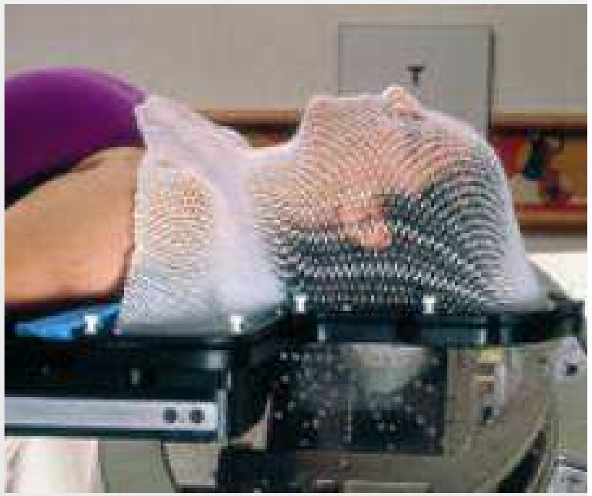
Head, neck and brain immobilization

- In the past, patient for head & neck cancers were taped to the tablet across their forehead a bite block was often used in order to tilt the neck in a reproducible manner.
- Today's methods for head & neck and brain tumors include a variety of head rests, masks, molds and frame systems.



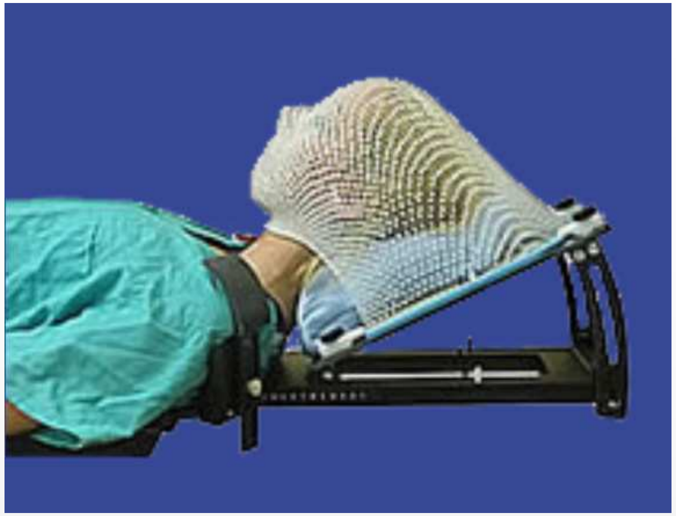
Head, neck and brain immobilization

- Aquaplast is the most common immobilization device used to treat head & neck cancers.
- This device is made from a rigid plastic that becomes pliable when placed in warm water.
- When it is wet, it is placed over the patient body and conforms to the contour of the treatment area.



Shoulder retraction

- Shoulder retraction: In patients with short neck or in patients where opp lateral fields are used to treat the neck, the shoulders need to be retracted caudally to avoid entrance and exit doses.
- An elastic strap, equipped with handles and attached to each side of the treatment couch, can be used for the patient to pull on.



AccuFix™ Cantilever Board with Shoulder Depression

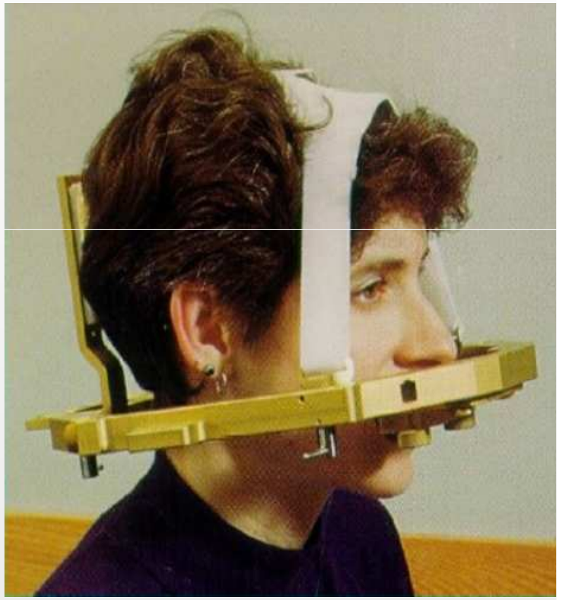
Combifix Shoulder Retractor

Immobilization in brain tumours

- Immobilization becomes more complex for radiosurgery or gamma knife procedures, because the requirements for positional and numerical accuracy in dose delivery are **± 1mm** and 5% respectively.
- Hence highly precised and accurate reproducibily is needed.
- Two types of fixation systems are used in radiosurgery
  - Gill-Thomas-Cosman (GTC) frame for fractionated therapy
  - Brown-Roberts-Wells (BRW) system for single fraction radiosurgery.

Immobilization in brain tumours

- 1) GTC relocatable head ring is a non invasive device that can be repeatedly fixed to the patient‘s head in precisely the same position.
- It has an impression taken of the patients upper dentition and the mold is then mounted to the head ring.
- An impression is also taken of the occiput to conform to the shape of the patient‘s head.



Immobilization in brain tumours

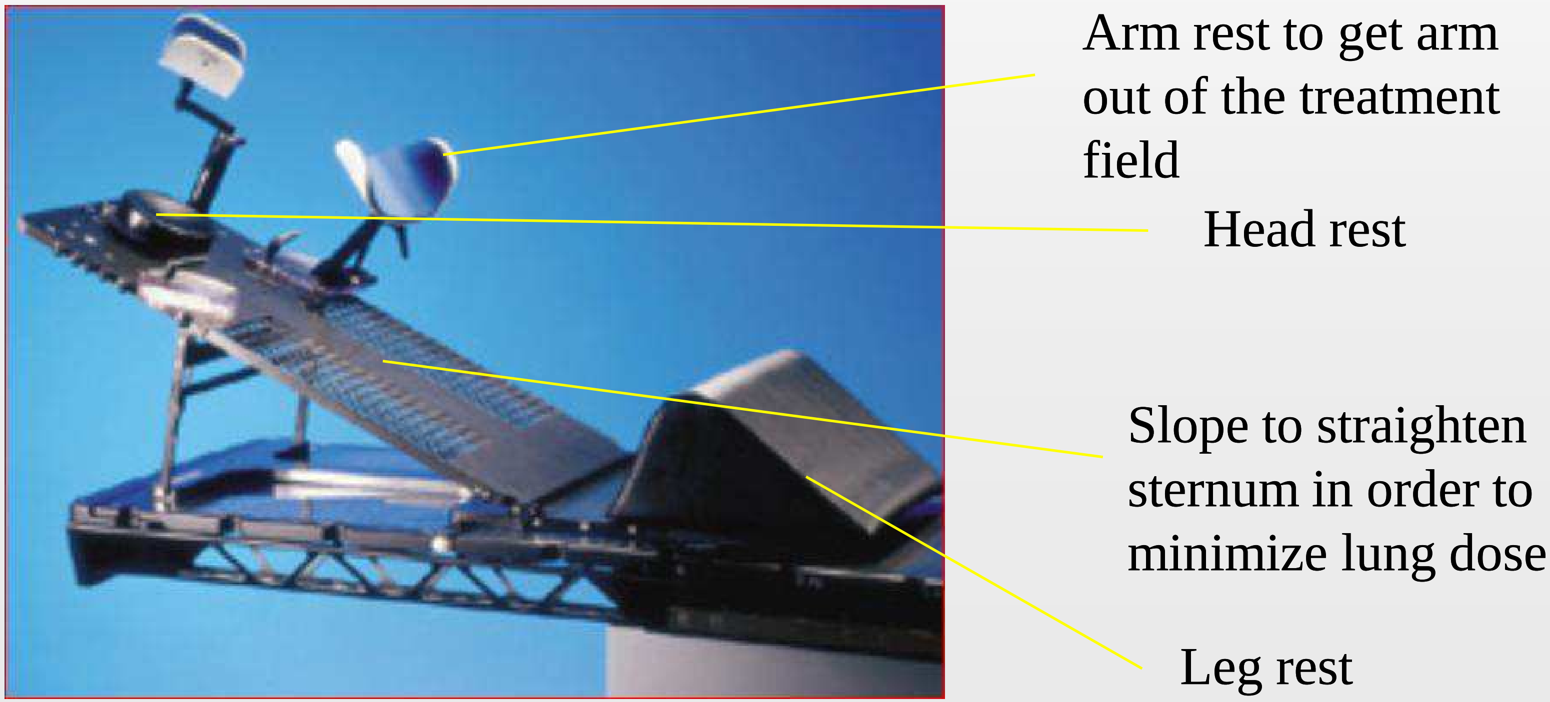
- 2) In single fraction radiosurgery, invasive procedure is followed, the patient is fitted with a BRW system and then bolted to the treatment table. Bolts are fitted and screwed into the patients skull to minimize any movement during treatment.

Thorax and breast immobilization

- There are two common immobilization systems used when treating tumours in chest cavity.
- 1) VACLOK: These are custom, beanbag type pillows that are placed around the patients upper body.
- The air is then vaccumed out of the bag for a custom fit and sealed in order to retain its shape.
- Vacloks are radiotranslucent, almost air equivalent, they are washable and reusable.

Immobilization/set-up devices

- 2) Breast board: Is used specifically for the treatment of breast cancer.

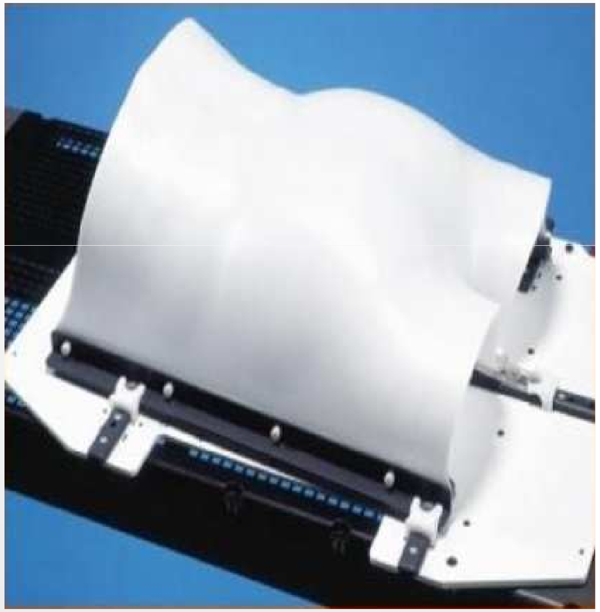


Pelvic immobilization

- There are two different crucial aspects in the immobilization of pelvic region.
  - to properly maintain patients outer contour during treatment. With respect to isocentre.
  - other is related to variation of internal structures during daily treatments.
- Immobilization systems such as vacloks, belly boards, and the hip-fix (using aquaplast) system are commonly used during treatments of pelvic region.

Pelvic immobilization

- Most of the pelvic malignancies are treated with partial body casts.
- A mask from the patient‘s mid thorax to upper thighs is made by streching warm, pliable thermoplast over the patient and then securing that mask to the pelvic board by a locking system.
- Windows on either sides can be cut on the mask, so that skin tatoos are visible and can be used for alignment.



Pelvic immobilization

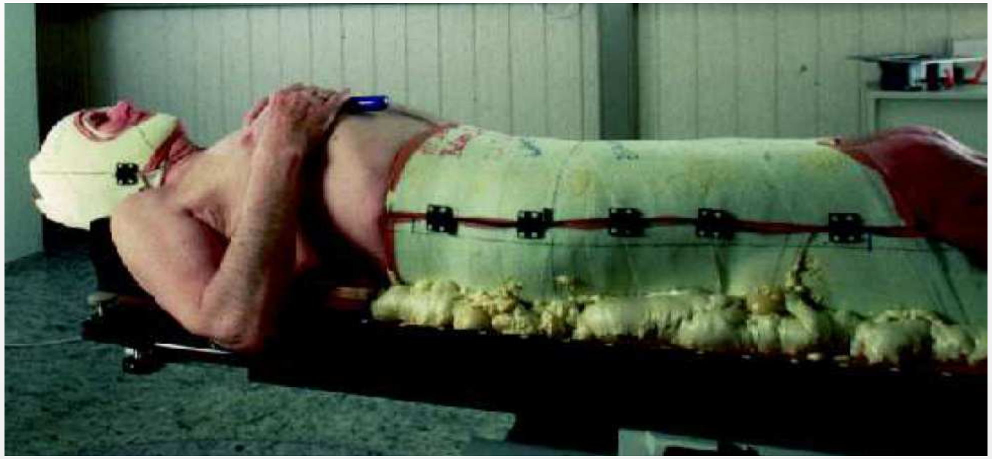
- A vaclok can also be used for immobilization in pelvic treatments.
- It should extend from the lower thoracic area to the mid thigh.
- Vacloks are popular choice for hip and pelvic positioning due to patient comfort and set up reproducibility.

Belly board

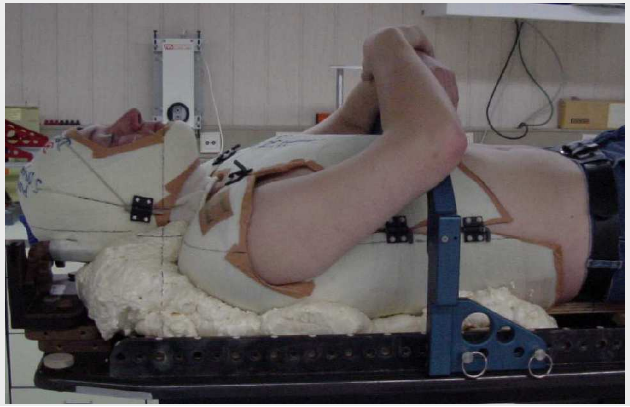
- Belly boards are used when the patient is treated prone.
- Belly boards allow the small bowel to drop below the lateral field to avoid severe side effects of irradiation.
- Use of the belly board significantly decreases the average volume of bowel that would otherwise be within the lateral field during standard box technique treatment.

Whole body irradiation

- Hard masc system plus torso (for Prostata-Ca)

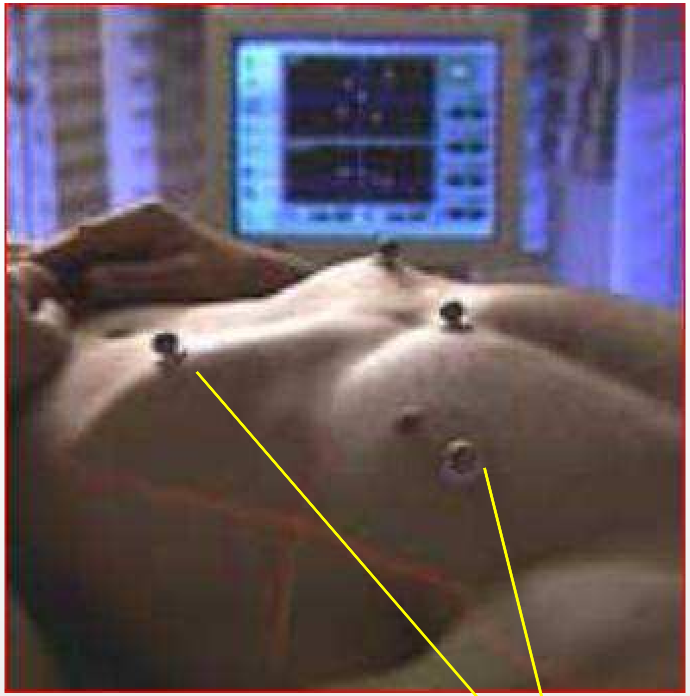


- Hard masc system plus torso (for paraspinal tumors)

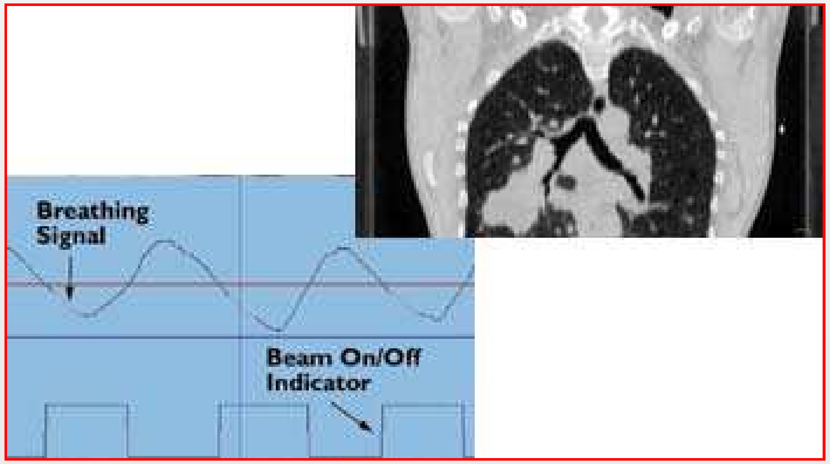


… sometimes movement is difficult to control ...

- Example: Lung motion due to breathing
  - determine motion and gate radiation beam



External markers on the patient which can be tracked by a video system



Low cost solutions

- Ask patients to
  - hold still
  - have reproducible bladder filling (example: always full or always empty)
  - provide dietary advise
  - breath shallow
- Make patients feel comfortable and secure

References

- IAEA Training Material on Radiation Protection in Radiotherapy, Radiation Protection in Radiotherapy, Part 10, Lecture 4: Treatment verification and reporting, "RT10_EBT4_GoodPractice_Verification_WEB.ppt"
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Thanks for your Attention