Patient Set-up and Immobilisation
The objective of this lecture is to integrate our knowledge of the differences between 2D and 3D planning and apply the same to various clinical sites. The final aim will be to be able to make out these differences and apply this knowledge to the clinic, critically analyse the plans generated and apply this in day to day selection of plans for treatment.
Specific Learning Objectives

• To understand the need for accuracy in advanced radiotherapy
• To understand the different types of set-up errors in radiotherapy
• To understand the process of patient positioning
• To know the difference devices available to aid patient positioning
• To learn practical methods of positiong for common cancer sites.
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Very Important

This slide series is training material for advancing from 2-Dimensional Radiation Therapy (2D) to 3-Dimensional Conformal Radiation Therapy (3DCRT) and to Intensity Modulated Radiation Therapy (IMRT)

BUT NOTE

The principles of good radiation therapy must be effectively applied to 2D before embarking on 3D or IMRT. Thus excellent immobilisation and accurate set-up guided by well executed computer planning must be the norm for all treatment techniques in a department before considering 3D or IMRT.
Introduction

- **Reminder of the goal of radiation therapy**
  - Precise delivery of high dose to the target volume
  - Destruction of tumour tissue
  - Limited dose to surrounding normal tissue/organs
    - Minimize acute and long term toxicity risk

- **To achieve the treatment goal we need to:**
  - Accurately position patient for each treatment
  - Eliminate body movement and minimize organ motion during treatment
    - Inadequate dose to tumour may lead to local recurrence
    - Limit target and critical normal tissue movement

The treatment as planned for must be accurately delivered for each and every fraction.
Clinical Rationale: 3D and IMRT

- **Achievement of dose escalation:**
  - To improve loco-regional control
  - To increase overall survival
- **Reduction of normal tissue complications:**
  - To improve quality of life

This requires a high level of accuracy!

An increase of the CTV is needed to accommodate for a set-up margin (SM) thereby yielding a PTV. Reducing the SM results in a smaller target volume. The high dose volume and normal tissue irradiated are less. 3D and IMRT are techniques to minimize the range of dose variation and improve the impact of the treatment.
Accuracy

• Dosimetric accuracy
  – Dealt with in other presentations in this series

• Geometric accuracy
  – The focus of this presentation

Accurate treatment requires understanding of errors.
The impact of geometric errors increases with the conformality of the radiation therapy treatment. There are essentially 2 different errors; mechanical and Set-up errors.

Presenter can extend or limit discussion on errors but focus is on set-up errors in this presentation:

- distribution of random errors
- most common systematic set-up errors recorded by participants
- systematic errors have the largest impact
- Set-up error determined relative to the isocentre, the field borders or both
- Gross error
- Individual and population systematic errors
- etc.

Systematic errors have the largest impact on the margin needed to adequately dose the target. The greatest benefit is gained from strategies to reduce systematic errors. Example is where no immobilisation device is used to stabilise the patient, the careless use of an immobilisation device, inaccurate recording of positioning co-ordinates or a badly constructed immobilisation system that has poor configuration and freedom of movement.
Set-up Error (1)

- **Random Errors:** Inconsistent deviation
  - Patient movement and organ motion
  - Inconsistent repositioning
  - Variables in equipment and devices
  - Inconsistent interpretation of skin marks
  - Etc.

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Set-up Error (2)

- **Systematic Positioning Errors**: Recurring error
  - Target delineation error
  - Change in target position and/or shape
  - Transfer error
  - Misinterpret set-up instructions
  - Blocks incorrectly cut/prepared
  - Discrepancies between simulator, treatment unit etc.
  - Treatment plan transcription errors
  - Etc.

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The risk of mechanical errors are reduced by good equipment quality control procedures including acceptance testing, maintenance and regular mechanical check as per schedule on a daily, weekly and monthly basis. Independent checks must be done periodically to ensure cross-checking of maintenance and quality procedures.

Random errors are often due to patient positioning and transfer of information as well as patient movement. Proper education and training of RTT are essential to ensure interpretation of marks, diagrams etc are uniform.

Systematic errors are minimised with careful documentation of procedures during simulation and set-up.
Patient Set-up and Positioning
Positioning the patient for treatment is a very important first step. Poor patient positioning will make planning and delivery of treatment difficult and sometimes impossible.
In this example, parallel pair treatment is used for a limb sarcoma. With poor positioning, the beam will enter and exit through the contra-lateral leg.
Accuracy is a requirement throughout the radiotherapy process. Here the accuracy in patient set-up is stressed.

The patient is a great source of errors. Therefore ensure the patient is comfortable so that he/she can remain still throughout the procedure.

The use of bony landmarks must be documented carefully. Tattoos are useful to ensure accurate alignment.

**Principles of accurate set-up**

- Place patient in comfortable, relaxed position
- Always check that the patient is straight
- Use modern laser system
- Extend the surface markings superiorly and inferiorly
- Reference the patient position (e.g. tilt of head) and field to external anatomical landmarks (and to bony landmarks wherever possible) and record carefully
- Make use of immobilisation devices
Principles of accurate set-up (2)

- Be sure that all set-up and positioning instructions are adhered to for every treatment
- Never work alone and be sure that every set-up is checked by **minimum of 2** qualified RTTs
- Only start the treatment when absolutely sure the set-up is correct

The basic of safe set-up is to ensure no one works alone and a counter check is done independently.
Three co-ordinate system

1. Patient co-ordinate system
   – Defined during localisation and (virtual) simulation
   – Comfortable, reproducible position that will become treatment position
   – “Permanent” fiducial marks on skin or immobilisation device
     • Choose taut and relatively immovable skin
       – Avoid soft and flabby areas
     • Reference skin marks to bony landmarks (manual or via imaging system)
Three co-ordinate system (2)

2. Room co-ordinate system
   – Origin is the isocentre of the external beam unit
   – All indicators relate to the isocentre and corresponding horizontal and vertical planes of the central axis

3. Beam co-ordinate system
   – Central ray of the radiation beam and X and Y axes in a plane orthogonal to the central ray
   – Origin is the isocentre of the external beam unit
   – Rotates relative to the room co-ordinator system
In an accurate set-up the treatment fields correspond exactly to the planned fields. This is only the case if the anatomical structures are aligned to the surface fiducial markers. In fact there are likely to be differences between the localised patient information, the surface markers and the anatomy.

Depending on the level of accuracy required alignment by use of surface fiducial 3-point triangulation used in conventional treatments may not suffice. There are specialised systems in use and being developed (e.g. stereotactic radiosurgery system).

The more rigid the body of the patient the more chance there is that accurate and reproducible set-up will be achieved.
In-room lasers allow alignment of patient in all 3 axes to ensure reproducibility of set-up.
Equipment can be discussed in more or less detail. This is an opportunity for some discussion on what each participant has, positioning of lasers, what isocentric means etc.

- In-room lasers
- Collimators (symmetrical, asymmetrical or multi-leaf)
- Isocentric Gantry (360° rotation)
- Isocentre stable to within 1mm radius
- Central axis passing through isocentre for all gantry angles and collimator rotations with radius 1mm
- Light field indicator and cross wire aligned exactly to central axis
- Precision couch
- CT or cone beam imaging with reconstruction accuracy of 0.5mm sphere
Importance of immobilisation

- Immobilisation is critical:
- To ensure the same volume is treated each day
- To ensure that critical structures (OAR) are excluded from the treated volume
- To provide confidence that the PTV may be safely reduced without risking geographical tumour miss

Immobilisation increases accuracy of treatment reducing dose to OAR
Although comfort is not the same as immobilisation a patient should be able to relatively easily maintain a position for the entire treatment and the position must be able to be exactly reproduced for each treatment.

When a patient cannot easily maintain a position for the entire treatment and/or when the position cannot be exactly reproduced for each treatment then an immobilisation device is used for fixation.
Types of devices

- Vary in construction from simple to highly complex.
- Can be made locally or by commercial vendors
Examples of immobilisation and positioning aids

- Tapes
  (cloth, masking tape, velcro etc.)

Sellotape and head rest alone are unsatisfactory (position is likely to vary from day to day). Only put on list because some departments in developing world still use these.

Stereotactic radiosurgery is not the topic of this presentation and only listed as it offers discussion point for ways to achieve high level of accuracy but is not practical for fractionated treatment regimes.
Generic body support
(foam wedges, head rests, stirrups, knee support etc.)
Body casts
(foam casts, vacuum bags,
thermosplastic etc.)
Multi-use positioning devices (breast board, head board, bite block system, elevation/rotation system, belly board, treatment chair)
In moving from 2D to 3D therapy, changes to treatment positioning may be required. With 2D planning, the image intensifier arm is far from the patient and there is little restriction in movement.

With 3D planning, especially with the use of large immobilisation devices eg breast board, the whole set-up of patient and equipment may not fit into a conventional CT scanner which has a small bore, typically about 70cm.
Wide bore CT scanners are available for radiotherapy planning. These scanners usually have a bore size of 80 – 90 cm depending on manufacturer, with a correspondingly large field of view (FOV). This enables different set-up positions to be possible.
Key criteria of immobilisation and positioning devices

- Device is rigid and will maintain shape
- Patient comfortable, relaxed and fully supported
- All movement constrained
- Device conforms to patient’s external contours
- Path of beam unobstructed
- Device can be used on simulator, CT, MRI etc. and on the treatment unit
- Surface dose will not be adversely affected
- Reference marks can be placed on the device
- Cost is in line with benefit and is affordable
Verification of set-up

- All treatments require at least spatial registration of the protocols and/or images of the planned field(s) with the patient position and field parameters at the treatment machine.
- Beam parameters and documentation should be second checked by an independent RT before the first treatment session.
- For 3D CRT and IMRT, a person who is familiar with the treatment plan should be present at the first setup.

A definition/discussion of PTV (Planning target volume) may help here.

The detail of treatment verification is given in another presentation in this series.
Immobilisation and diagnostic CT

- Accuracy is compromised when simulation position and treatment position is not identical
- Any patient positioning systems used should fit into the bore of the CT scanner
Brain and Central Nervous System (CNS)

- The treatment of some conditions e.g. AVMs, acoustic neuromas, brain metastases, primary brain tumours require a high level of precision (<1mm overall geometric uncertainty).

- Commercial systems available to aid accuracy.
  - One example is the stereotactic head ring for single fraction radiosurgery. The apparatus is fixed to the patient’s head by screws into the skull bone. This facilitates exact localisation and positioning.

AVM: Arterio-venous malformation
Doses up to 70 Gy give improved loco-regional control. However this comes with greater acute toxicity and long term complications.
Challenges to optimal radiation therapy of H&N

- Close proximity of tumour and critical structures/organisms
- Tolerance of normal tissue limits delivery of optimum high dose
- Contour variations and tissue heterogeneity present a challenge to dosimetric planning
- Set-up uncertainties exist (5mm-1cm)
Radiation Therapy in the H&N

• Need for:
  – More conformal delivery to optimize the treatment
  – High-precision techniques

• Conformal radiation therapy and adequate high dose by:
  – Improved immobilisation devices for achievement of reproducible treatment position
  – Technology to aid accurate patient set-up
  – Advanced computer planning systems to accommodate for; compensation for missing tissue, customized shielding, integrated brachytherapy or small volume boosts etc
  – Introduction of 3D, IMRT etc.
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Most commonly used:

- Thermoplastic masks
  - 3 Clamp
  - 4 Clamp
  - 5 Clamp

The fixation force, precision and stability of immobilisation by means of low melting temperature thermoplastic devices depends on:
  - Type of thermoplastic material
  - Design of head board/rest
Guidelines for positioning

- Localize patient with neutral, hypo- or hyper-extension of the neck position as relevant
  - Minimize intra-fraction patient motion
- Use customized head rest and mask
  - Improve accuracy
- Index immobilisation devices to treatment couch
  - Improves set-up efficiency and accuracy
- Use active patient position monitoring system (LED camera System)
  - Improves set-up accuracy and reproducibility
  - Minimize intra-fraction patient motion
Breast

• Multi-use breast board:
  – cost effective
  – can be accurate

• BUT
  – Record configuration at planning/simulation accurately and fully
  – Verify configuration for each patient carefully for each treatment
Example of breast radiotherapy patient positioning with both arms up
All breathing management systems rely on the relationship between a surrogate (implanted fiducial marker, external fiducial marker usually tracked in real time by use of a video system, external surface monitoring, lung volume, air flow) to estimate the tumour position at any given time. This is not entirely accurate and work continues as our understanding of motion and its impact on treatment improves. Additional verification is needed to improve accuracy.
Trunk
Ultrasound has been used for daily check of prostate position relative to markers. This requires a dedicated ultrasound machine and training for RTT, physicists or physicians doing the procedure.

- **Prostate movement is combination of:**
  - pelvic set-up variation
  - internal organ movement
    - Peristalsis
    - Gas in rectum
    - Bladder filling
    - Deep breathing to a lesser extent
- **Radiographic localisation and tracking of implanted markers**
- **Ultrasound-based systems**
Paediatrics

• Young children present special challenges.
• Positioning must achieve high levels of accuracy to treat effectively but limit normal tissue toxicity.
• Take time to gain child’s trust in order to make well fitting immobilisation and positioning device.
• Wherever possible avoid general anaesthesia or even sedation.
Take home messages

- 3D and IMRT with associated dose escalation and normal tissue sparing require:
  - Rigid immobilisation
  - Accurate positioning and patient set-up
  - Restriction of systematic and random errors
  - Reproducible treatment delivery
References

- The Royal College of Radiologists, Institute of Physics and Engineering in Medicine and Society and College of Radiographers. On target: ensuring geometric accuracy in radiotherapy.

ICRU: International Commission on Radiation Units and Measurements
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