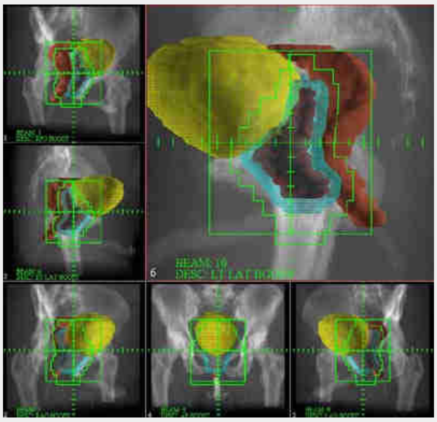
Your role as a Radiation Therapist

RT's are **group of professionals with direct responsibility for the administration of radiation therapy to cancer patients.**

Responsibilities: technical planning and delivery of the radiation dose
clinical care
psychosocial care of the patient on a daily basis
preparation, treatment and immediate post treatment phases.

The multidisciplinary team (MDT): Radiation Oncologist or Clinician, Medical Oncology Radiation Physicist (ROMP), Nursing staff and RT's.0

Beam's eye view (BEV)



Prevention of Accidental Exposures

"Radiation therapy involves many steps between prescription and dose delivery. Each step may involve a large number of parameters that must be selected, adjusted, recorded and communicated between different professionals."

Failure can result in failure to control the disease

Anatomical Terms

Anatomical position: This is a standard point or frame of reference that describes the human body when it is standing erect, facing forward, feet together flat on the floor, the arms slightly raised from the sides with the palms facing forward.

Anatomical Terms (cont)

Anterior: Also known as **ventral** and refers to being in front of an organ or at the front of the body

Posterior: Also known as **dorsal** and refers to behind an organ or at the back of the body.

Superficial: Refers to on or close to the surface of the body.

Proximal: Refers to locations that are close to the point of origin of a structure or attachment to the body.

Distal: Refers to locations that are further away from the point of origin of a structure or attachment to the body.

Inferior: Refers to organs or structures that are below another.

Superior: Refers to organs or structures that are above another.

Medial: Refers to organs or structures closer to the midline of the body.

Lateral: Refers to organs or structures that are further away from the midline of the body.

Supine: Refers to a person lying face up.

Prone: Refers to a person lying face down.

Oncology terminology cont.

Primary tumour refers to the original tumour in the body– the site where the cancer first started.

Metastatic tumour or metastasis is a tumour in a site other than its site of origin

Metastatic cancer has the same morphological name and the same histological composition as the primary tumour. For example, prostate cancer that spreads to the bones and forms a metastatic tumour is metastatic prostate cancer, not bone cancer.

THE PLANNING PROCESS

The goal of radiation therapy planning is to evaluate the possible treatment approaches and choose one that:

1. Gives the best dose distribution to the tumour whilst minimising the radiation dose delivered to surrounding healthy tissue

2. Is reproducible

3. Is verifiable

The steps in the radiation therapy planning process include:

1. Establishing the **patient's treatment position**, constructing a patient repositioning immobilisation device (when needed), obtaining a volumetric image data set of the patient in treatment position (usually CT, and often also MRI and/ or PET imaging)

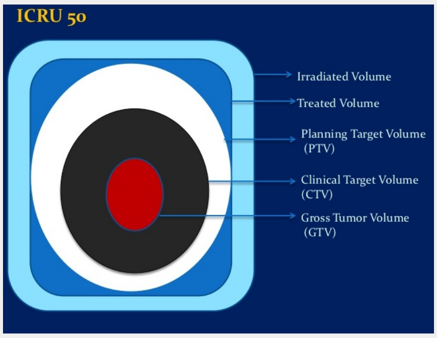
2. **Contouring target volume(s) and organs at risk** using the volumetric planning image data set

3. **Specifying a prescription dose** for the Planning target volume (PTV) and dose-volume constraints for any OARs, which includes:
a. **Forward planning**—determining beam orientation and designing beam apertures, and computing a 3D dose distribution according to the dose prescription
b. **IMRT inverse planning**—set up initial beam orientations and enter optimisation parameters (i.e., dose-volume constraints for PTV(s) and all regions of interest) and initiate TPS optimisation process which generates beam fluences, resulting dose distribution, monitor units, and leaf motion files

4. **Evaluating the treatment plan**, and if needed, modifying the plan (e.g., beam orientations, apertures, beam weights, etc.) until an acceptable plan is approved by the radiation oncologist

5. **Approved plan** must then be **implemented on the treatment machine** and the patient's treatment **verified** using appropriate QA procedures.

Volumes



Tolerance doses

Tolerance doses are often represented as TD5/5 or TD 50/5.

TD5/5 is an estimate of the dose that will give a 5% probability of a given late effect 5 years after treatment. Similarly TD 50/5 is the dose giving a 50% risk of a particular effect at 5 years.

These measures are useful for serial organs such as spinal cord, where exceeding the dose threshold at any point can compromise the whole organ function

A graphical plot of the dose of radiation and the percentage of volume of a anatomical structure can be produced by the radiation therapy treatment planning systems and is know as a **dose volume histogram (DVH).**

Effect of body shape on isodose distribution

The isodose curve shape is influenced by the patients shape (**external body contour**) and the difference in the densities of the tissues (**inhomogeneities**) within the area of interest.

A **hot spot** is an area of high dose and a**cold spot** refers to areas of under dosing

A hot spot becomes clinically meaningful when the minimum diameter of the dose region is greater than 15mm.

Effect of body shape on isodose distribution (cont)

The effect of changing tissue density on the isodose distribution isodose curves are created from dose output data measured in water or a water equivalent phantom. The density of water is 1.0gm/cc and is similar to that of soft tissues such as muscle and fat in humans

Bone and air however have different tissue densities than soft tissue or water which needs to be accounted for in the planning process.

When using CT data to plan, radiation therapy treatment planning computer systems perform this correction by allocating a CT number to tissue within the scan based on tissue density. This ability to quickly and efficiently account for **tissue inhomogeneity** has greatly enhanced radiation therapy dose calculations.

Methods of treatment planning

Forward planning The ability to orient beams in 3D allows Radiation Therapists to develop treatment plans that use non-coplanar beams.

Inverse Planning The major differences between forward planning and IMRT inverse planning is the use of a computer optimisation program that requires a formal description of the requirements using a mathematical objective function and constraints that are used by the program to find the solution.

Volumetric Modulated Arc Therapy (VMAT) is a type of intensity-modulated radiation therapy (IMRT) treatment technique that uses the same hardware (i.e. a digital linear accelerator) as used for IMRT or conformal treatment, but delivers the radiotherapy treatment using a rotational or arc geometry rather than several static beams.

The Process

The process of radiation therapy treatment planning (or often referred to just as planning) calls for the integration of the physical findings and diagnostic imaging information with knowledge of the pertinent anatomy, pathology, and natural history of the patients particular tumour type

BEV

Beams eye view (BEV) shows a **reconstruction of the patients images (CT images)** to create a **digitally re-constructured radiogragh (DRR)** with an overlay of the radiation fields as viewed from the radiation beam itself i.e the **beams eye view**. The example above shows 6 different angles of the BEV for a pelvic treatment.

Blue is the volume to be treated with radiation

Yellow the bladder

Orange/brown the rectum.

Green square is the field size, that is set on the linear accelerator, and the jaggered teeth like shapes in green are the **multi-leaf collimators (MLCs)**

The area within the MLCs is where the radiation is directed.

Anatomical Planes

Frontal or Coronal: is a vertical line that divides the body or structure into anterior and posterior sections. It runs lengthwise through the body.

Sagittal: Also known as the **lateral** plane and is a vertical line that divides the body or structure into left and right sides. It runs lengthwise through the body.

Transverse: Also known as the **axial** or **cross-sectional** plane. It is a plane that runs horizontally through the body or structure and divides it into superior and inferior sections.

The role of Radiation Therapy

Radical Intent: To cure or shrink early stage cancer

Adjuvant therapy prevents cancer from coming back

For cancers that can be cured either by radiation or by surgery, radiation may be preferred because it can sometimes preserve the organ's function

Chemotherapy acts as a **radio-sensitiser**, a drug that makes the cancer cells more sensitive to radiation

The drawback of giving chemotherapy and radiation together is that side effects tend to be worse. It's often better to use radiation before or after chemo.

If a type of cancer is known to spread to a certain area, doctors often assume that a few cancer cells might already have spread there, even though imaging scans (such as CT or MRI) show no tumours.That area may be treated to keep these cells from growing into tumours.

Palliative Intent: To treat symptoms caused by advanced cancer

Sometimes cancer spreads too far to be cured. Some of these tumours can still be treated to help relieve symptoms

Radiation might help relieve symptoms such as pain, trouble swallowing or breathing, or bowel blockages that can be caused by advanced cancer.

Radiation therapy CT-simulator

A radiation therapy CT-simulator consists of a diagnostic quality CT scanner, laser patient positioning/marking system, virtual simulation 3D treatment planning software, and various digital display systems for viewing the digital reconstructed radiographs (DRRs)

The CT scanner is used to acquire a volumetric planning CT scan of a patient in treatment position.

Organs at risk (OAR)

The organ at risk is an organ whose sensitivity to radiation is such that the dose received from a treatment plan may be significant compared with its tolerance, possibly requiring a change in the beam arrangement or a change in the dose.

Specific attention should be paid to organs that, although not immediately adjacent to the CTV, have a very low tolerance dose (e.g. the eye lens during nasopharyngeal or brain tumour treatments).

Planning Organ at Risk Volume (PRV) a margin is added around the OAR to compensate for that organ's spatial uncertainties

Dose criteria for OARs typically depend on the organ's biological architecture

Serial organs (such as the spinal cord) often have a maximum dose constraint

Parallel organs (such as lung) are frequently planned using more complex dose-volume constraints

Medical terminology

Prefix or Suffix	Meaning	Example
a-, an-	denotes an absence of	apathy
ab-	away from	abduction
-al	pertaining to	abdominal
brachy	short	brachytherapy
-crine	to secrete	endocrine
cry(o)-	cold	cryoblation
endo	inside or within	endocrinology
-graph	record or picture	electrocardiograph
hemi-	one half	cerebral hemisphere
itis	inflammation	tonsilitis
neo-	new	neoplasm

Dosimetry

Isodose lines or curves give a visual, as opposed to a tabular, representation of the dose at various positions across the radiation field. The data for each isodose curve is obtained from measurements acquired in a homogenous, usually water filled phantom, where all the points within a radiation field have the same percentage depth dose

Single field isodose distributions are of limited use in the treatment of deep seated tumours, since they give a higher dose near the entrance at the depth of dose maximum than at depth.

Guidelines for single photon beams:

Dosimetry (cont)

• A reasonably uniform dose to the target (±5%);
• A low maximum dose outside the target (<110%);
• No organs exceeding their tolerance dose.

Single fields are often used for palliative treatments or for relatively superficial lesions (depth < 5–10 cm, depending on the beam energy)

Penumbra is defined as the region near the edge of the field margin where dose falls rapidly. The width of the penumbra is influenced by: the size of the radiation source, the source to collimator distance, and the SSD.

Multi-field isodose distributions When multiple beams are utilised for a patient treatment, isodose distributions provide an effective means of visualising the resultant combined beam dose.

Inserting a beam modifier such as a wedge or tissue compensator may modify isodose distributions.

Wedge pair. Two beams with wedges (often orthogonal) are used to achieve a trapezoid shaped high dose region. This technique is useful in relatively low lying lesions.

Four field box. A technique of four beams (two opposing pairs at right angles) producing a relatively high dose box shaped region. The region of highest dose now occurs in the volume portion that is irradiated by all four fields. This arrangement is used most often for treatments in the pelvis, where most lesions are central. Opposing pairs at angles other than 90º also result in the highest dose around the intersection of the four beams.

Three field box. A technique similar to a four field box for lesions that are closer to the surface (e.g. rectum). Wedges are used in the two opposed beams to compensate for the dose gradient in the third beam.

Beam modification devices

Wedges

Wedge Factor (WF) is the ratio of doses at a reference depth with and without wedge for identical field size under similar experimental conditions.

Bolus is a tissue equivalent material placed in contact with the skin to achieve one orboth of the following: increase the surface dose and/or compensate for missing tissue.

To increase the surface dose, a layer of uniform thickness bolus is often used (0.5–1.5 cm), since it does not significantly change the shape of the isodose curves at depth.

To compensate for missing tissue or a sloping surface, a custom made bolus can be built that conforms to the patient's skin on one side and yields a flat perpendicular incidence to the beam.

Magnification Factors

Images such as digitally reconstructed radiographs (DRR's) used in radiation therapy simulation, treatment and planning all display an enlarged or magnified image of the object of representation. This occurs as the imaging device is always placed a greater distance from the object being imaged. The degree of magnification is dependent on the geometric arrangement of the source (or x-ray target), the patient or object being imaged, and the imaging device

The divergence or spread of the radiation beam is directly proportional to the distance from the source.

To determine the magnification factor of an image we need to know the target to image distance and the target to object being imaged distance, or the size of the object being measured.

This geometric relationship is used to determine the **magnification factor (MF).**

Planning of radiation fields

Contemporary treatment-planning computers allow the incorporation of 3- dimensional anatomic data into the planning of radiation fields

With **beam's eye view (BEV)** technology, radiation delivery can be planned so as to ensure that the radiation field adequately covers the target and spares or minimises the dose to the non target healthy tissues

Planning of radiation fields cont.

Radiation therapy is a **clinical discipline that is strongly influenced by constant change in technology.**

Recent developments:

• Advances in computerised treatment planning;

• Developments in electronics;

• Research in biological effects of radiation;

• Advances in radiation protection;

• New technologies in the areas of cancer diagnosis;

• Refined visualisation of tumours /human anatomy;

• Research and understanding of genetics;

• Understanding individual responses to treatment regimes

The aim is to deliver an adequate dose of radiation to the tumour, whilst minimising dose to the surrounding normal tissues.

Medical terminology

Combining form	Meaning
adeno	gland
cardi/o	heart
bronch/o	bronchus
arthr/o	joint
cephal/o	head
chrondr/o	cartilage
cis/o	to cut
col/o	colon, large intestine
cyst/o	sac, bladder, cyst
derm/o	skin
haem/o	blood
lymph/o	lymphoid tissue or lymph gland
mast/o	breast
my/o	muscle
opt/o	eye
oste/o	bone
pnem/o	lung, respiration, air
rhin/o	nose
thorac/o	chest

Oncology terminology

Ocology (Greek 'oncos' = tumour) is concerned with the **study and treatment of neoplasms. Neoplasm** means 'new growth'.

Neoplasms can be either **benign** (non-cancerous), **in situ** (pre-cancerous) or **malignant** (cancerous).

Cancer is the general term given to a range of neoplasms, occurring when a group of cells grows and multiplies uncontrollably. Approximately **200** different types

Abbreviations:

Adj: adjuvant therapy

BCC: basal cell carcinoma

bx: biopsy

Ca: cancer or carcinoma

Chemo: chemotherpay

Gy: gray (unit of radiation equal to 100 rad)

mets: metastases

NED: no evidence of disease

TNM: tumour node metastases (this is a staging system for tumours)

Pre-planning and the planning process

Prior to commencing any Radiation Therapy treatment several factors must be considered:

1. Patient factors – previous radiation therapy if any, relevant past medical history, performance status, age, social situation, patients wishes and likelihood of compliance

2. Tumour factors – type of tumour, extent of disease, natural history of disease, treatment intent, treatment options, expected toxicities, known clinical outcomes of treatment management approaches.

STAGING AND PRE- PLANNING

Staging is determining the extent of the patients' disease, after which **treatment intent** is decided ie. radical (curative, adjuvant) or palliative.

Pre-planning and the planning process (cont)

Radical treatment generally requires higher doses of radiation with the intent of disease control.

Adjuvant radiation therapy is delivered in addition to another cancer treatment (often surgery). Adjuvant treatment is given after the primary treatment to lower the risk that the cancer will come back.

Palliative treatment is delivered with the primary intent to relieve pain, and improve quality of life. Palliative doses of radiation therapy are generally lower and delivered over a shorter duration of time.

Once treatment intent is determined, the Radiation Oncologist provides a **treatment prescription.**

This radiation therapy prescription defines:

•**Treatment volume** the area to be treated

• **Dose of radiation** in Gy

• **Fractions** :The total number of radiation treatments

• **Dose per fraction**

• **Frequency of treatment** (daily, twice a week, twice a day etc);

• **Constraints** to healthy organs surrounding the tumour (**organs at risk** or OAR)

• The **planning technique** or approach to delivering the intended treatment may also be specified by the Radiation Oncologist, or in some situations or clinical centres this decision is determined by the Radiation Therapist, or possibly as a team decision.

These factors are all essential to establish prior to planning commencing.

Defining the treatment volume

Internal Margin (IM) takes into account the variations in size, shape, and position of the CTV

Set-up Margin (SM) takes into account all uncertainties in patient-beam positioning.

The **IM** is referenced to the patient's coordinate system using anatomical reference points and the **SM** is referenced to the treatment machine coordinate system.

IM uncertainties are due to **physiologic variations** (e.g., filling of bladder or rectum, movements due to respiration, etc.) and are difficult or almost impossible to control from a practical viewpoint.

SM uncertainties are related largely to **technical factors** that can be dealt with by more accurate setup and immobilisation of the patient and improved mechanical stability of the machine.

Internal Target Volume (ITV) is the volume formed by CTV and IM

Planning target volume (PTV) is formed by the CTV, and the IM and SM combined. It is the volume required to receive the prescribed dose of radiation.

GTV – Gross tumour volume: the palpable or visible extent of malignant tumour.

CTV – Clinical tumour volume: is the GTV with a margin added to include sub clinical spread of disease. The CTV is usually stated as a fixed or variable margin around the GTV (e.g. CTV = GTV + 1 cm margin), but in some cases it is the same as the GTV (e.g. prostate boost to the gland only).

Treated volume: the actual volume enclosed by the isodose distribution representing the prescribed dose of radiation.

Irradiated volume: the volume that has received a significant radiation dose in relation to normal tissue tolerance.

Defining the treatment volume (cont)

Photon beam radiation therapy is carried out with a variety of beam energies and field sizes under one of two set-up conventions:

a constant **Source to surface distance (SSD)** for all beams

an isocentric set-up with a constant **Source to axis distance (SAD).**

In an SSD set-up, the distance from the source to the surface of the patient is kept constant for all beams, while for an SAD set-up the centre of the target volume is placed at the machine isocentre.

Five field radiation technique.

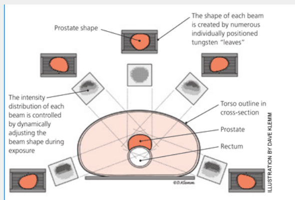


Figure 1.6 Shows each of the 5 beams and the position of the rectum posteriorly to the prostate. You can see the grey boxes illustrate the prostate volume from each of the 5 angles and how this changes in 3 dimensions and therefore required the field shape to change.

Dose Calulations

Radiation therapy treatment planning systems (RTTPS) are utilised extensively to produce an appropriate isodose plan

Reference dose – need to determine what the dose will be at 100% isodose. This is usually isocentre with isocentric techniques or at Dmax for fixed SSD techniques. If a fixed SSD technique is used and prescribed at a depth other than Dmax, the dose delivered at 100% needs to be calculated and applied. For example, if a dose of 4 Gy per fraction is prescribed at a depth of 5cm when treating a lumbar spine, which has a %DD of 94%, the dose at 100% would be 4.26Gy per fraction. This value would be used on the top line of the calculation.

Dose Calulations (cont)

TAR/TPR – Tissue Air Ratio or Tissue Phantom Ratio. The only difference between these labels is the depth used to calibrate the data (1.5cm vs 10cm), which is why TPR tends to be used with higher energies. If you are treating with a fixed SSD technique, the TAR will not be applied as the isocentre is on the skin surface. This factor takes into account the scatter conditions in tissue

OF/CCF/ASF – Output factor/Cone Correction Factor/ Area Scatter Factor. These are all the same thing, but may be labelled differently depending on which department you go to. All take into account the change in scatter conditions from the jaws with different field size.

WF and PF – Wedge factor and Plate factor Any accessories in the path of the beam will attenuate the beam, and this needs to be taken into account when calculating monitor units.

ISL/IVSLF – Inverse Square Law or Inverse Square Law Factor needs to be taken into account when treating at a distance that is not the calibrated distance (i.e. 100cm) as this will alter the beam properties. The formula for **ISL** is: (Source to Calibrated Distance ÷ Source to Ref Point Distance) 2 X100 – Linacs calibrated for **centigray**, but generally prescribing in **Gray**, so need to multiply all by 100.

Normal Tissue Tolerance

Acute responding tissues: express injury during or within 2-3 weeks of the completion of radiotherapy e.g., skin, oral mucosa

Late responding tissues: express injury several months to years after irradiation e.g., kidney, lung.

In clinical radiation therapy the volume of tissue irradiated is an important factor determining the clinical tolerance of an organ.

Normal Tissue Tolerance (cont)

The risk of major late effects is usually dose limiting in radiation therapy.