

Imaging practices in Radiotherapy

Dr Colin J Martin ICRP Committee 3 on Protection in Medicine







Imaging practices in Radiotherapy (RT)

- Use of images in planning and verification of RT treatments
- Imaging modalities available
- The benefits and risks from imaging
- Frequency of imaging during RT treatment
- Optimisation of verification imaging
- Recording patient doses for kV cone beam CT imaging



Conformal Radiotherapy



- Conformal treatment fields are delivered from multiple directions to focus the therapeutic high dose on the tumour
- The machine continuously reshapes the beam and changes the intensity as the gantry moves around the patient
- This enables the radiation fields to be conformed more accurately to tumour shapes and allows doses to healthy tissues surrounding the tumour to be reduced
- Improvements in treatments can only be realised if patients are positioned precisely and radiation fields are delivered with mm accuracy.
- This requires imaging.

Image guided radiation therapy (IGRT)

Images of patient recorded for:

- Planning
- Verification immediately before and during treatment delivery to adjust for positional uncertainty
- Assess response at a later stage



Treatment planning images



RT centres throughout the world use Computed Tomography (CT) as the main planning technique Other imaging techniques are used in treatment planning depend on the availability

- Positron emission tomography
- Magnetic resonance imaging
- Ultrasound
- Single photon emission tomography



Verification images to guide treatment



Imaging requires fields covering the area surrounding the tumour for position verification

Facilities for imaging on linear accelerators

- kV imaging systems: x-ray tube and image detector plate can rotate around the patient and record planar or cone beam CT (CBCT) images
- Main technique used during treatment
- MV therapy source: can be used with electronic portal imaging devices to produce images, but contrast is poor and doses are higher
- Normal tissues are irradiated and there is an associated risk of second primary cancers

Magnetic resonance imaging integrated into linacs are offering an alternative to CBCT without the use of ionising radiation but are much more expensive than CBCT and are in use 10%-20% of RT centres in many countries.

Optical surface guidance is based on projection of a light pattern onto the patient's skin which is monitored using video cameras and allows assessment of set-up based on a large area of the patient's body.



Ultrasound provides real-time, volumetric imaging. It has reasonable soft tissue contrast and is useful for pelvic and abdominal imaging.

Non-ionising techniques are used in about half of RT centres for some treatments



The balance between imaging dose and reduction in treatment margins

- Dose margins around tumour targets are used to account for uncertainty in delineation, anatomical changes, positioning and movement
- More frequent imaging allows margins to be reduced to protect normal tissue.



Imaging frequency

- Image guidance may allow doses to the tumour target to be raised if doses to critical organs at risk can be reduced
- Cumulative doses from imaging will contribute to risk of second primary cancers.
- There is a balance between reducing high dose margins around a target and lowering doses from imaging to surrounding normal tissues
- Imaging requires justification and optimisation

Adaption of imaging protocols and recording of imaging doses

- Options for optimising RP:
- Frequency of imaging
- Volume of tissue to be imaged
- Level of image quality required



Survey of RT imaging practices

- Surveys have shown that vendor protocols are frequently not optimised for radiological protection
- 90% of RT centres use vendor imaging protocols for CBCT in 2/3rd countries surveyed
- Adjustments can be made to imaging parameters, so that the doses from imaging are reduced without necessarily reducing image quality
- Fewer than 50% of RT centres make adjustments to protocols for individual patients



Optimisation and patient dose surveys

Need for patient dose information

• Optimisation of radiological protection requires a knowledge of patient imaging doses

Survey of Radiotherapy Departments

- 50% of European RT centres recorded patient imaging doses
- <10% of RT centres in other parts of the world record patient imaging doses</p>

Measurable dose quantity for kV CBCT

- Cone Beam Dose Index (CBDI)
- Measured in PMMA cylindrical CT phantom
- With 100 mm pencil ionisation chamber
- Gantry rotated with wide beam covering phantom



Amer et al. 2007. Imaging doses from the Elekta Synergy x-ray cone beam CT system Br. J. Radiol. 80 476–82



Recommendations for optimisation of radiological protection of imaging in RT

- Need for allocation of resources for image dose assessment and optimisation of radiological protection for imaging.
- Optimisation of image quality and dose should be a part of the purchasing, acceptance, commissioning and quality assurance process
- Image Optimisation Teams comprising radiation oncologists, technologists and medical physicists should be established
- Optimisation Teams should review imaging protocols in respect of image quality and dose at regular intervals
- Vendors should include displays of measurable dose quantities (CTDI_{w,IEC}) linked to exposure factors for imaging systems



Summary

- Improvements in radiation treatment delivery require accurate patient positioning
- Imaging is needed for both planning and verification of patient setup
- Radiation fields for imaging expose normal tissues surrounding the target
- The dose from imaging needs to be justified and the technique used optimised
- kV cone beam CT is the main imaging technique used during treatment
- Most centres frequently image at every fraction
- Most centres use protocols supplied by vendors with limited optimisation
- Data is needed on doses received by patients from imaging to allow optimisation to be carried out



I acknowledge contributions from the members of ICRP Task Group 116

William Small, Daniel Berger, Sebastien Gros, Aurelie Isambert, Stine Korreman, Tomas Kron, Choonsik Lee, Tom Merchant, Ung Ngie Min (Vincent), Jenia Vassileva, Tim Wood

TG116 Mentees participating in surveys of RT practices

Abdel-Hai Benali, Abdullah Abuhaimed, Aliaksandr Miadzvetski, Ana Cravo Sá, Anja Lazovic, Anson Ho-Yin Cheung, Francisco Mosquera-Pena Sánchez, Habib Alsaleh, Hein Fourie, Hossam Ragab Shaaban, Isabelle Nilsson, Lavanya Murugan, Liang Runcheng, María Cristina Plazas d'Leon, Marianna Koutrouli, Mario Djukelic, Mirta Dumancic, Piotr Pankowski, Samara Prass dos Santos, Snezana Vostini, Yiannis Roussakis, Zakiya Al Rabhbi



Thank you for your attention

