Implementing 3D conformal radiotherapy and IMRT in clinical practice: Recommendations of IAEA-TECDOC-1588

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Goal of radiation therapy

• Conformity of dose distribution to a 3D target volume at the same time minimizing the dose to an acceptable level to the surrounding healthy structures

• Achieve local (or regional) control with limited risk of normal tissue complications
Conventional radiation therapy

Shaped field defined from planar radiograph
3D conformal radiation therapy
Full 3D CT dataset; ICRU 50,62 definition of target and OAR volumes
IMRT

Full 3D CT dataset; ICRU 50,62 definition of target and OAR volumes; co-registration of PET and CT images
IMRT (3DCRT) planning and delivery process

- Positioning and immobilization
- Image acquisition
- Structure segmentation
- Treatment planning and evaluation
- Plan validation as necessary
- Treatment delivery and verification
- Position verification
- File transfer and management

Adapted from an illustration presented by Webb, 1996
IMRT

Requires knowledge and understanding of

- patient immobilization/organ motion
- volumetric imaging
- 3D heterogeneous dose calculations
- large-scale optimization
- dynamic beam delivery of non-uniform beam fluences
IMRT - advantages

• Highly conformal, even concave dose distributions
• Large dose gradient near the perimeter of both the target volume and healthy structures
  ➢ Potentially allows for AHARA [as high (dose) as reasonably achievable]
  ➢ Decreased dose to normal tissue
• Improvement of therapeutic ratio
However...

• Increased conformity of IMRT may lead to “geographical miss of the tumor” due to inadequate target delineation, organ motion, patient positioning inaccuracies.

• A larger margin may lead to unacceptable high dose to adjacent normal critical structures.
Clinical implementation of IMRT

• Equipment and space requirements
• Staff training and patient education
• Time and personnel requirements including their responsibilities
• Changes in treatment planning & delivery practices
• QA of equipment and individual patient treatments
• Changes in scheduling & overall integration

See also: IAEA TECDOC 1588
Clinical implementation of IMRT: Highlights

Equipment

• Linac
  • MLC
  • OBI/CBCT
  • Gating

• Shielding

• Imaging
  • CT Sim (MRI, PET/CT)
  • EPID, port films
  • 4D CT (optional)

• TPS
  • Inverse planning
  • R&V
  • 2nd check software

• Immobilization

• QA/Dosimetry
  • Chamber/diode array or film/EPID dosimetry
  • MLC QA (film/EPID)
Clinical implementation of IMRT: Highlights

Training

Physicians

• Cross-sectional anatomy
• Inverse planning concepts, dose constraints
• Margins, effects of organ motion
• DVH based planning and analysis
• Plan evaluation—dose conformality/heterogeneity
• Dose prescription
• Limitations of IMRT

See also: IAEA TECDOC 1588
Clinical implementation of IMRT: Highlights

Training

In addition to the previous ones

Medical physicists

- Understanding of optimization methods
- Characteristics of IMRT dose distributions, plan QA
- Beam modeling and delivery for IMRT

See also: IAEA TECDOC 1588
Clinical implementation of IMRT: Highlights

Training

Medical oncologist
• IMRT/SRS/SBRT

Radiologists
• PET

Additional Staffing

• Increased time for planning and delineation of target volume (Physician, planner)
• Image guidance
• Increased treatment time/delivery/QA

TUMOUR STAGING WITH PET (18F-FDG)
Self questions to be asked!!

• What can be achieved with IMRT?
• What specific dose goals should be given to specific treatment sites?
• What are the dose/dose-volume tolerances of organs at risk?
  ➢ How is this affected by fractionation?
• How are achievable results affected by margins-immobilization, localization, treatment delivery method, TPS and dose calculation method?
Modern radiotherapy is complex

Hardware breaks, software always has bugs, and people make mistakes!

Every clinic is susceptible to these kinds of errors (i.e., BIG ones)!
Reported accidental exposures with new technologies

• Keeping equipment in calibration is essential
• Few events resulted from machine errors
  ➢ Micro-multileaf collimator
  ➢ VARiS IMRT/MLC
• However, each had a strong human failure
• The vast majority of events begin with a staff error

ROSIS database; ICRP Draft 2009
Assessment of dose

I should pay more attention to the Medical Physicist next time...
ICRP draft 2009

Risk-informed and cost-effective approaches for prioritizing tests and checks by means of prospective methods of risk assessment, to be performed in cooperation with manufacturers
Risk assessment

• What is Risk?
  - A term which frequently embodies
    - probability of an event occurring and
    - severity should such an event occur
  • Need to quantitate probability and severity

• New tools
  - Process tree
  - FMEA
  - Fault tree

AAPM TG100: A new paradigm for QA in radiation therapy
Conclusions

- Human factors
  - Training
  - Miscommunication within and between departments
- Lack of attention by people performing task
- Lack of consistent procedural guidelines
- People as well as linacs, need to be “commissioned”
- Lack of comprehensive QA, QC & QM programs

AAPM TG100: A new paradigm for QA in radiation therapy
Our job is not to prevent errors, but to keep the errors from injuring the patients.

Lucian Leape

It is useful to report all accidents before consequences appear.

It is impossible to make anything foolproof because fools are so ingenious.

Artur Bloch, Murphy's law