IMAGING AND THERAPEUTIC RATIO

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Effect of Underdosage and Overdosage

Effect of Tumor Dose

- Tumor Control
- Late Normal Tissue Damage
Evolution of Radiation Technology with Imaging
2D – 3D- Molecular Imaging

• Clinical Planning with anatomical landmarks
• Orthogonal X-rays 2D
• CT based planning – 3D
• MRI: adds better soft tissue delineation
• Molecular Imaging
2D Image Based

- Wider margins based on bony landmarks
- Difficulty in OAR delineation
- More normal tissue irradiated
- Increased toxicity
- Reduced therapeutic ratio at tumouricidal doses
Theoretical Basis

IMAGING

- Reduce the uncertainty of microscopic extension
- Precise localization of the tumor and/or target volume and sensitive structures

IGRT

- Reduce the uncertainty in the set-up and identify and reduce organ motion
- High selectivity in radiation dose administration
- INCREASE of RADIATION DOSE and DOSE per FRACTION

IMPROVEMENT IN LOCAL CONTROL

- Reduction of safety margins
- REDUCTION of COLLATERAL DAMAGE to OAR
3D Image Based

- Implications of ICRU 50/62: GTV, CTV
- 3D tumor volumes/OAR delineation
- Accurate normal tissue delineation
- Shields, custom blocks, MLC to protect normal tissues
- Reduced dose to normal tissues
- Improved Therapeutic Ratio
Volume Based Planning

- Gross tumour volume
- Clinical target volume
- Planning target volume
- Treated volume
- Irradiated volume
CT

- 3D Volumes for tumor and OAR
- Electron Density data for planning
CT versus MRI
MRI

• Better visualization of soft tissues due to better soft tissue contrast
• Allows improved delineation of RT treatment volumes
• MR images can be acquired in any spatial plane and as high resolution volumetric data sets
• Extremely useful in pelvic/brain tumors
• Fusion possible with CT for planning
MRS

- NAA – Neuronal marker
- Creatine – metabolic activity
- Choline – cellular proliferation
- Lactate – anaerobic glycolysis
- Choline peak,
- Reduced NAA, creatinine
- Lactate – increased in necrosis
MRI & MRS

Combination of MRI and 3D-MRSI acquisition of an “image of spectra

NAA
N – Acetylaspartate (NAA)

Cr
Cho

Tumor
Cho
Necrosis
Dynamic MR Perfusion

- Cerebral blood volume (CBV)
- Increased – both high and low grade tumors
- Reduced – radiation necrosis
- Highest vascularity – site of biopsy
PET

- Metabolically active areas
- Biological target volumes
- Dose escalation to improve TR
Prostate

- Escalation of radiation dose is one of the major strategies currently being explored in an attempt to improve rates of local control and overall survival in prostate cancer.

- As the dose to the prostate is increased, the risk of side effects, particularly to the rectum and bladder/urethra, increases.
Prostate
Limitations of CT

• Limitations of visualization of soft tissue boundaries between prostate gland and other pelvic organs (similar x-ray attenuations)

• Most difficulty in visualizing the apex (data suggests that cancer is present in the apex in up to 75% patients)

• Transaxial plane of imaging can result in partial volume averaging effects
MRI

• T2 weighted images provide the best internal architecture of prostate and seminal vesicle involvement
Dominant Intraprostatic Lesion

- Magnetic resonance (MR) imaging can facilitate prostate delineation and tumor (DIL) localization.
- In 67% of tumors, the location of the tumor can be correctly depicted at high-spatial-resolution T2-weighted MR imaging by using a 1.5-T endorectal coil.
- The addition of findings from proton MR spectroscopic imaging results in a 90% sextant positive predictive value.
- Findings from multisection fast dynamic contrast material–enhanced MR imaging can also provide additional information.
- The combination of data from T2-weighted MR imaging, dynamic contrast-enhanced MR imaging, and MR spectroscopic imaging has been previously shown to provide up to 93% localization accuracy.
- Thus, tumor localization with MR imaging appears to be at a level that is suitable for use with IMRT planning.
Images show integration of T2-weighted MR, dynamic contrast-enhanced MR, and 3D spectroscopic image information into a single tumor map.
Registered tumor map overlaid in red on top of transverse treatment-planning CT image

Dominant Intraprostatic Lesion DIL
Radiation therapy treatment plan.
Role of Imaging in Cancer cervix

• CT
  Treatment Planning
  LN assessment
• MRI
  Extracervical Spread
  Design of lateral portals
• PET
  LN involvement
Cervix

Lymph node evaluation

Infiltrating Myometrium/Endometrium
Cervix

Parametrial

Pelvic wall Invasion
Cervix

Bladder Invasion      Rectal Invasion
Brain Tumors

- Advantage of MRI for standard tumour delineation is obvious
- Use $T_2$ – weighted images
Conventional vs IMRT
Functional MRI
Functional MRI

• Dose to functional OAR is reduced when it is defined as a constrained organ in the optimisation
  – 21% of the motor cortex 45 Gy when planned conventionally
  – 9% when IMRT is used (without specific OARs)
  – 2% when IMRT is used and fMRI data is included as OAR.

CT/MRI in Head & Neck Cancer
Variations In Target Coverage with CT/ MRI

Where Do we Stand?.....Where Do we Go?

Emami et al IJROBP, 2003
Variations In Target Coverage with CT/ MRI fusion
In Nasopharyngeal Primary

MRI & CT are complementary

Emami et al IJROBP, 2003
PET CT Fusion And Effect On PTV

Reduction In size of PTV at Primary

Primary

GTV CT/GTV PET = 3

Node

Node PET/Node CT= 0.7

Heron et al IJROBP, 2004
PET

• Before PET, CT scanning represented the most accurate imaging modality for planning RT in lung cancer. It was a major advance over the use of plain X-rays.

• Limitations of CT
  Use of the conventional CT criterion of short axis transverse diameter greater than 1cm to determine if there is tumor in a mediastinal lymph node is notoriously inaccurate. CT cannot detect tumor in normal-sized lymph nodes. CT cannot usually delineate the boundary between atelectasis and tumor clearly.
Value of PET CT in defining gross tumor volume (GTV) in atelectasis. Tumor is readily apparent on PET/CT image enabling reduction in treatment volume.
Advantage of PET

• PET has contributed in reducing the GTV by 25% in NSCLC

• Reduced normal tissue inclusion

• Improved TR

IJROBP NOV 2005
Conclusion

• Conformal Radiation has evolved parallely with evolution in imaging from 2D to 3D
• It is possible to use imaging for accurately delineating the target and OAR’s
• Combination of imaging modalities has helped to reduce irradiated volume
• This has resulted in improving TR
• Future rests with functional and molecular imaging to further improve the therapeutic ratio