Contouring and prescribing for specific clinical sites for IMRT

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Regional Training Course on Basics of Intensity Modulated Radiotherapy
Melbourne Australia, 9-13 September 2015
Aims

To introduce concepts on target volumes and organs at risk for specific clinical sites

To introduce an understanding of uncertainties and need for protocols in clinical implementation of IMRT
Learning Objectives
(Training Curriculum Reference 13)

Target Volumes: GTV, CTV, ITV, PRV, PTV
IMRT Dosimetry
DVH and Organs at Risk (OAR)
Image-guided radiotherapy

Assimilating Biology, Imaging (CT, MRI, PET), Dosimetry and Delivery
Target Volumes

Definitions – ICRU 50/62

Gross Target Volume (GTV)
Clinical Target Volume (CTV)
Internal Target Volume (ITV)
Planning Risk Volume (PRV)
Planning Target Volume (PTV)

A: Linear margins
B: Probabilistic margins
C: Safety margins
Gross Tumor Volume (GTV) + Microscopic Spread + Internal Motion + Set-up Errors

Clinical Target Volume (CTV)

Internal Target Volume (ITV)

Planning Target Volume (PTV) - treated volume
Gross Tumor Volume (GTV) + Microscopic Spread + Internal Motion + Set-up Errors

Clinical Target Volume (CTV)

Internal Target Volume (ITV)

Planning Target Volume (PTV) - treated volume

Respiratory gating

Imaging
CT, PET, MRI

Biology

Set-up Errors

In room imaging
Risks with Margins

- Generous margins
- Conservative margins

Field Margins

Physically/Biologically necessary margins

Imaging “certainty”

Geographic and marginal miss
## Local Failure Rate: Orbital Lymphoma

**Whole Orbit**
- Local Recurrence: 0% (0/12)
- Grade 2 Toxicity: 33% (4/12)

**3D-Conformal**
- Local Recurrence: 33% (4/12)
- Grade 2 Toxicity: 25% (3/12)

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Engels B, IJROBP Jun 1;74(2):388-91, 2009

p=0.02
3D-CRT vs. IMRT
Implications for target definition

• Concave vs Convex targets

• Quality Assurance/peer review:
  
  – 3D-CRT beams are more readily compared to “historical beams” (conventional), whereas IMRT beams/plans are not able to be checked via intuition.

• Dose gradients/margins
3D-CRT vs. IMRT

Implications for target definition

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• Dose gradients/margins
3D-CRT:
All beams cover all of target
Always yields a convex shape

PTV
3D-CRT:
All beams cover all of target
Always yields a convex shape

IMRT:
Can it give a concavity?
3D-CRT vs. IMRT
Implications for target definition

• Concave vs Convex targets

Issues & Pitfalls
PET-CT & MRI: Complementary and Supplementary information
Image fusion & co-registration: Volume changes of OARs,
  “Flatness” of image (MRI)

Access and Expense
3D-CRT vs. IMRT
Implications for target definition

• Concave vs Convex targets

• Quality Assurance/peer review:
  – 3D beams are more readily compared to “historical beams”, where IMRT beams/plans are less able to be checked via intuition.

• Dose gradients/margins
3D-CRT

Beams Apertures

CT

Contour Segment

IMRT

Dose Constraints

Inverse planning

DVH, Intensity Maps

Assess doses, beam orientation & aperture

Assess DVH’s, Beam orientations, “apertures”, intensity maps not intuitive
The Multi-Disciplinary Team

Pathologist
CT, MRI, PET

Patient and Target Immobilisation

Peer Review: Intra- & Inter-observer variations

Follow-up: cancer control and late effects

Figure 1.1 A typical 3-D CRT Process. The right column shows the staff involved in each step.
Target Volume Definition

There is at least one thing not right with the planning CT scan.
Target Volume Definition

There is at least one thing not right with the planning CT scan.
Target Volume Definition

Need for Reproducible Rectal diameter: Bowel instructions
Target Volume Definition

Need for Image Guidance: Fiducial Markers
3D-CRT vs. IMRT

Implications for target definition

- Concave vs Convex targets

- Quality Assurance/peer review:
  - 3D beams are more readily compared to “historical beams”, where IMRT beams/plans are less able to be checked via intuition.

- Dose gradients/margins
  - (examples to follow)
Target Volume Definition

- Imaging: Anatomy & Functional

- Immobilisation (Patient & Target)

- GTV, CTV (biology), ITV, PTV

- Organs at Risk (variable volumes)

- Understanding of Dose inhomogeneity, DVH and Dose Constraints
  - (ICRU 83)

- Understanding of Accuracy of Dose Delivery: Image guidance & Equipment
Contouring and prescribing for specific clinical sites for (3D-CRT and) IMRT

Examples:
Prostate, Prostate Bed, H & N, Lung, and Ano-rectum.
Prostate

Definitive: High Risk, T2bN0M0, GS 4+4, PSA 10.5ug/L
- 78Gy/39# @5/week

Post-op: pT3aN0M0, R1, GS 3+4, PSA 0.2
- 70Gy/35# @5/week
IAEA

Prostate: Definitive RT

Red: Prostate  Green: Seminal Vesicle
Prostate: Definitive RT  Contours in 3D view
### Prostate: Definitive RT

#### Template Objectives

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Prostate: Definitive RT

Image Guided Radiotherapy

Daily On-Board Imaging

IGRT
Prostate

Definitive: High Risk, T2bN0M0, GS 4+4, PSA 10.5ug/L

- 78Gy/39# @5/week

Post-op: pT3aN0M0, R1, GS 3+4, PSA 0.2

- 70Gy/35# @5/week
Post-Radical Prostatectomy Radiotherapy

- Contouring guidelines

1. Anatomic boundaries of the clinical target volume (prostate bed) after radical prostatectomy.


Sidhom MA, Kneebone AB, Lehman M, Wiltshire KL, Millar JL, Mukherjee RK, Shakespeare TP, Tai KH.


3. Technology assessment of automated atlas based segmentation in prostate bed contouring.


*Radiat Oncol. 2011 Sep 9;6:110.*


Post-Op Positive Apex Margins  Axial views
Post-Op Positive Apex Margins Axial, Sagittal & Coronal views
Prostate: Post-op RT  Template Objectives

Plan Objectives

- **PTV_7000**
  - At least 90% receives more than 1.900 Gy: 66.50 Gy: 66.803 Gy
  - Mean dose: 1.986 Gy: 69.50 Gy: 70.044 Gy
  - At most 2% receives more than 2.140 Gy: 74.90 Gy: 71.951 Gy
  - At most 98% receives more than 2.000 Gy: 70.00 Gy: 69.129 Gy

- **Rectum**
  - At most 20% receives more than 2.000 Gy: 70.00 Gy: 63.736 Gy
  - At most 25% receives more than 1.857 Gy: 65.00 Gy: 60.775 Gy
  - At most 30% receives more than 1.714 Gy: 60.00 Gy: 56.900 Gy

- **Femur_L**
  - At most 30% receives more than 1.714 Gy: 60.00 Gy: N/A
  - At most 60% receives more than 1.286 Gy: 45.00 Gy: N/A
  - At most 99% receives more than 1.000 Gy: 35.00 Gy: N/A

- **Femur_R**
  - At most 30% receives more than 1.714 Gy: 60.00 Gy: 27.529 Gy
  - At most 60% receives more than 1.286 Gy: 45.00 Gy: 21.468 Gy
  - At most 99% receives more than 1.000 Gy: 35.00 Gy: 1.589 Gy

- **Bladder**
  - At most 35% receives more than 2.000 Gy: 70.00 Gy: 60.689 Gy
  - At most 50% receives more than 1.857 Gy: 65.00 Gy: 48.821 Gy

- **Penile Bulb**
  - Mean dose is less than 1.500 Gy: 52.500 Gy: N/A
Prostate: Post-op RT

DVH

Graph showing dose volume histogram with data for various structures and dose statistics.
Prostate: Post-op RT  IGRT: Cone Beam CT
H & N

Parotid Tumour: SCC metastatic from Skin Cancer

- 66Gy/33# @5/week
H&N: Parotid Tumour  Contours & Dosimetry
Why is this a IMRT plan?
Why is this a IMRT plan?

Peter Mac
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H&N: Parotid Tumour  OARs and DVH

Dose Volume Histogram

- Relative dose [%]
- Dose [Gy]
- Ratio of Total Structure Volume [%]

- Mandible
- Source ID: C1
- Plan ID: RT F&N
- Equiv. Sphere Diam. = 3.0 cm

RT F&N - Dose Volume Histogram
H&N: Parotid Tumour  Daily IGRT with OBI
Lung

Adenocarcinoma: Right Lower Lobe
T4,N1 (bone erosion)

60Gy/30# @5/week
Lung: Contours & Dosimetry
Lung: DVH
Lung

Daily IGRT with OBI
GI

SCC of Anus: Chemo-radiotherapy

54Gy/30# @5/week

Mitomycin C + 5 FU
Anus & Regional LN: Contours
17 ‘fields’
### Anus & Regional LN: Beams & Dosimetry

#### Fields

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1522 MU
### Anus & Regional LN: DVH

**How should the small bowel be contoured?**

**Does your department have a protocol for DVH of the small bowel?**
SCC Anus  Daily IGRT with OBI
**Protocols**

### Radiation Oncology

**Clinical guidelines**

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For Breast Clinical Guidelines please refer to Breast Services Clinical Guidelines
Table of Contents

1 Outpatient Referral .............................................................................................................................................. 3
2 New Consultation ............................................................................................................................................... 3
3 Pre-treatment Investigations .......................................................................................................................... 3
4 Indications for Treatment ................................................................................................................................ 4
5 Management Options ....................................................................................................................................... 4
  5.1 Stage T1c, T2a/b N0 M0 ............................................................................................................................... 4
  5.2 Stage T2c N0 M0 and T3a N0 M0 .................................................................................................................. 4
  5.3 Stage T3b N0 M0 and Stage 4 (still treat with radical dose RT for bladder involvement) ......................... 4
  5.4 Stage Local recurrence post-prostatectomy ................................................................................................. 5
  5.5 Stage M1, IV - Incurable .............................................................................................................................. 5
6 Radiation Therapy Prescription, Anatomical Volume and Desired Dose ......................................................... 5
  6.1 Stage T1c, T2a/b N0 M0 ............................................................................................................................... 5
  6.2 Stage T2c N0 M0 and T3a N0 M0 .................................................................................................................. 5
  6.3 Stage T3b N0 M0 .......................................................................................................................................... 6
  6.4 Local recurrence post-prostatectomy .......................................................................................................... 6
  6.5 Stage T3/T4 Locally Advanced - Palliative .................................................................................................. 6
  6.6 M1 - Bone Metastasis .................................................................................................................................... 6
7 Planning ......................................................................................................................................................... 7
  7.1 IMRT and Conformal Imaging Requirements ............................................................................................ 7
  7.2 Positioning Requirements and Localisation Devices .................................................................................. 7
  7.3 Treatment Area Delineation ....................................................................................................................... 7
  7.4 Computer Dosimetry Requirements .......................................................................................................... 7
  7.5 Dose Constraints (Also applicable for post-prostatectomy radiotherapy) .............................................. 8
    7.5.1 External Beam – Total Dose 84-78Gy ................................................................................................... 8
    7.5.2 External Beam – 46 Gy/23 fractions (combined with HDR boost) ..................................................... 8
    7.5.3 Non-rectal Bowel Volume (not small bowel) ....................................................................................... 8
    7.5.4 Small Bowel Volume ............................................................................................................................ 8
    7.5.5 External Beam Femoral Head Constraints .......................................................................................... 8
    7.5.6 External Beam Bladder Constraints .................................................................................................. 8
    7.5.7 7.4.7 Penile bulb Optional ................................................................................................................... 8
  7.6 Field Arrangements ...................................................................................................................................... 8
  7.7 Verification Process (Sim CT, Online Imaging) ........................................................................................... 8
  7.8 Special Considerations ............................................................................................................................... 8
  7.9 Treatment Sheet Requirements .................................................................................................................. 9
8 Treatment Verification/Quality Assurance ....................................................................................................... 9
9 Treatment Review ........................................................................................................................................... 9
10 Follow Up ....................................................................................................................................................... 10
Learning Objectives

Target Volumes: GTV, CTV, ITV, PRV, PTV
IMRT Dosimetry
DVH and Organs at Risk (OAR)
Image guided radiotherapy

Assimilating Biology, Imaging (CT, MRI, PET), Dosimetry and Delivery
Learning Objectives

Features for successful (IM)RT

Well trained Multi-disciplinary team

Radiation Oncologist: Biology, Contouring, Dosimetry review, Follow-up
Radiation therapist: Planning, Dosimetry
Medical physicist: QA, Dosimetry
[Nursing, Administrative support]

Adequate Equipment

Simulation (CT), RTPS, Treatment verification, Image guidance

Education and Training with Quality Assurance Protocols underpin the above: VMAT
Protocol driven:

Image acquisition

Treatment Planning System

Image-guidance & Treatment verification
2010
52 yo male
High Risk Prostate Cancer
cT2cN0M0, PSA 42ug/L, GS 4+4

May 2011
Completed Neoadjuvant ADT + IG-IMRT 78Gy/39#
Gr 2 GI toxicity, No GU toxicity
PSA 1.9ug/L

July 2012
Completed Adjuvant ADT
PSA 0.3ug/L

October 2012
PSA 0.24ug/L
January 2013
PSA 0.3ug/L

January 2014
GI toxicity resolved
PSA 0.7ug/L

November 2014
PSA 2.8ug/L “Biochemical Relapse”

March 2015
CT scan: External iliac LN, Asymptomatic
PSA 4.8ug/L
January 2013
PSA 0.3ug/L

January 2014
GI toxicity resolved
PSA 0.7ug/L

November 2014
PSA 2.8ug/L “Biochemical Relapse”

March 2015
CT scan: External iliac LN, Bone scan: negative
Asymptomatic
PSA 4.8ug/L

What treatment, if any, would you recommend?
July 2015
PSA 15ug/L
Ga$^{68}$ Prostate Specific Membrane Antigen (PSMA) - PET scan
Ga$^{68}$ PSMA-PET scan
July 2015
PSA 15μg/L
Ga\textsuperscript{68} Prostate Specific Membrane Antigen (PSMA) - PET scan

August 2015
ENZAMET clinical trial
- A randomised phase 3 trial of enzalutamide in first line androgen deprivation therapy for metastatic prostate cancer
- LHRH-agonist + bicalutamide/nilutamide/flutamide vs LHRH-agonist + enzalutamide
Acknowledgements

Jim Cramb

IAEA