Differences, changes to processes, additional requirements

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Regional Training Course on Basics of Intensity Modulated Radiotherapy
Melbourne Australia, 9-13 September 2015
Think “IMRT”

- Very much based in 3D CRT thinking
- Normal tissue sparing is the key
- Only the computer can tell you how to deliver
- A sound quality assurance program is essential
- IMRT requires more work of clinicians (contouring), physicists (commissioning and quality assurance) and RTTs (image guidance)
Local control

Identification of the target

Delivery of radiation

Excellent dose distribution

Precision targeting

The aim of radiotherapy
Local control

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IMRT

The aim of radiotherapy
Evolution of external beam radiotherapy

- Fixed SSD RT
- Isocentric RT
- Conformal RT
- IMRT
- IGRT

- Computer planning
- 3D planning
- Inverse planning
- 4D planning, adaptive re-planning

Better set-up
Better targeting
Better sparing
Less patient variability
Evolution of external beam radiotherapy

- Fixed SSD RT
- Isocentric RT
- Conformal RT
- IMRT, VMAT
- IGRT, Motion management

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Better sparing
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Computer planning
3D planning
Inverse planning
4D planning, adaptive re-planning
Evolution of external beam radiotherapy

- Fixed SSD RT
- Isocentric RT
- Conformal RT
- IMRT, VMAT
- IGRT, Motion management

Adaptive radiotherapy
- Computer planning
- 3D planning
- Inverse planning
- 4D planning, adaptive re-planning

SABR/SBRT

Better setup
Better targeting
Better sparing
Less patient variability

Decreased time

Reduction
Objectives of the presentation

• To introduce basic concepts for IMRT
• To discuss different methods to implement IMRT
• To highlight clinical and QA needs
• To introduce the IMRT workflow
• To discuss the challenges of introducing and IMRT program
Why more than conformal?

patient

Organ at risk

target
Why more than conformal?

(patient) -> target (Organ at risk) -> RT beams
Why more than conformal?

RT beams

patient

Organ at risk

target

Need fluence modulation to achieve organ at risk sparing

Beam profile
Organ at risk

Target

Radiation beams

Beam fluence profiles

High dose region

Organs at risk
Organ at risk
Target
Radiation beams
Beam fluence profiles
High dose region
Organ at risk
How can IMRT be achieved?

- Need method to determine which fluence distribution is required
- Need method to deliver the fluence
IMRT delivery methods

• Many different methods are available to achieve intensity modulation:
  • Compensators
  • Field in field
  • Step and shoot IMRT
  • Dynamic sliding window

• Several rotational methods
Compensators

- Physical compensators
  - lead sheets
  - brass blocks
  - customized milling

Beam profile

What more than conformal?
Multileaf Collimator (MLC)

- Used to define any field shape for radiation beams
- Several variations to the theme:
  - different leaf widths (1cm to 0.4cm)
  - replaces collimators or additional to normal collimators
Intensity Modulation

- Achieved using a Multi Leaf Collimator (MLC)
- The field shape is altered step-by-step or dynamically while dose is delivered
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Multiple (typically 7 to 10) fields - usually not equally spaced
Often 20 or more segments per field
Achievable dose distributions

Thyroid

Calvarial radiation

Vertebral body

Bauman et al 2007
Achievable dose distributions

This is achieved through increasing complexity: $>50000$ MLC leaf positions + dose delivery points

Bauman et al 2007
Treatment planning

Patient data

Treatment unit data

Acceptable plan

Treatment delivery
Treatment planning

1. Treatment unit data
2. Patient data
3. Treatment planning
4. Acceptable plan
5. Treatment delivery
Inverse treatment planning

1. Treatment unit data
2. Patient data
3. Define acceptable plan
4. Treatment planning
5. Treatment delivery
Inverse treatment planning

1. Treatment planning
   - Treatment unit data

2. Patient data

3. Define acceptable plan

4. Treatment planning

5. Make deliverable

6. Treatment delivery
IMRT delivery methods (continued)

• Some can be planned in a conventional way:

• Example: Field in field (adding one or few segments in existing fields to even out dose distribution)
Field in field technique for breast radiotherapy

- Conventionally planned
- Two opposing tangential beams
- Add few% more dose in small field(s) to largest separation
- Intensity modulated but not inverse planned
Dynamic IMRT dose delivery

Move MLC leaves as a function of dose delivered
Take home message

- IMRT delivers the same overall dose in many small fields
  - More flexibility
  - Longer beam on times
  - Possibly more leakage dose
  - Planning and delivery requires computer aid
Black box?
How dangerous is it… really?

Impact of complexity and computer control on errors in radiation therapy

B.A. Fraass

Department of Radiation Oncology, Cedars-Sinai Medical Center, 8700 Beverly Blvd., AC1085, Los Angeles, CA 90048, USA; e-mail: benedick.fraass@cshs.org
The data from the various studies of error rates in radiotherapy, comparing results dating from the 2-D radiotherapy age, through 3D conformal planning and treatment, to the modern IMRT era, are clear: the overall error rates have decreased significantly from approximately 1% per field or 3% per treatment session to <0.1% per session (probably approximately 0.03–0.05% per session). The number of errors that occur with highly complex and sophisticated computer-controlled treatment planning and delivery systems is much lower than before.
But need to think again…

- Data only from leading institutions which actually look at their errors
- Errors are likely to be under-reported (litigation risk)
- Types of errors are different:
  - Used to be random
  - More likely systematic now
Understanding is needed

- Training
  - Life long learning
  - Consider your set-up
  - Multidisciplinary

- Quality assurance
Quality Assurance essential

- Absolute dose at a point
  - Target
  - Critical structure(s)
- Monitor units cannot be verified intuitively

- Dose distribution:
  - Conformity to the target
  - Dose fall off to critical structure
- Ideally all in 3D!
Machine QA is VERY important
Communication

- Amongst professions
- With patients
- With other oncologists, radiologists, nuclear medicine physicians, urologists, surgeons, GPs, …
Recommendations by the ICRU

- International Commission on Radiation Units and Measurements
- ICRU reports provide guidance on prescribing, recording and reporting
- A new report on IMRT has been released in 2010 (ICRU report 83)
Contents of ICRU report 83

1. Introduction (3D CRT and IMRT)
2. Optimized treatment planning for IMRT
3. Dose Volume Prescribing and Reporting
4. Definition of Volumes
5. Planning Aims, Prescription and Technical Data
   • Appendix A: Physical Aspects
   • Appendix B: Clinical Examples
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>10 pages on Commissioning and QA

>400 references
What is IMRT? The ICRU point of view

Table 1.1. IMRT methods. The preferred optimization approaches for each IMRT method are described in Section 2.3.

<table>
<thead>
<tr>
<th>Type of method</th>
<th>Intensity modulation method</th>
<th>Preferred optimization approach</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compensators</td>
<td>A beam filter designed to provide a patient-specific intensity pattern designed by an optimization procedure</td>
<td>Optimized beamlets</td>
</tr>
<tr>
<td>Segmental MLC (step and shoot)</td>
<td>Multiple MLC segments delivered from each treatment direction</td>
<td>Direct-aperture optimization</td>
</tr>
<tr>
<td>Dynamic MLC (sliding window)</td>
<td>Leaves slide across the field at different rates</td>
<td>Optimized beamlets</td>
</tr>
<tr>
<td>Intensity-modulated arc therapy (IMAT)</td>
<td>Leaves move while the gantry is rotating. Can require multiple rotation arcs</td>
<td>Direct-aperture optimization</td>
</tr>
<tr>
<td>Serial tomotherapy</td>
<td>Gantry rotates around the patient with the couch fixed. Binary leaves modulate a fan beam. Upon completion of each rotation, the couch is moved in a step-wise fashion</td>
<td>Optimized beamlets</td>
</tr>
<tr>
<td>Helical tomotherapy</td>
<td>Gantry and couch move synchronously. Binary leaves modulate a fan beam</td>
<td>Optimized beamlets</td>
</tr>
<tr>
<td>Robotic radiotherapy</td>
<td>Multiple non-coplanar pencil beams delivered by a robot</td>
<td>Optimized beamlets</td>
</tr>
</tbody>
</table>
Common issues with 3D CRT are discussed - there are many

- IGRT
- Motion
- Adaptive RT
- Margins
- Radiation induced secondary cancers
  (compared to 3D CRT IMRT uses 2 to 3 times more mu)
IMRT reporting

- Dose and volume

Figure 3.1. Example of differential DVHs and their corresponding cumulative DVHs. The dose-volume metrics, $D_{\text{near-min}} = D_{98 \%}$, $D_{95 \%}$, $D_{50 \%}$ (median), and $D_{\text{near-max}} = D_{2 \%}$ are indicated for the PTV. For this example, the values of $D_{98 \%}$, $D_{95 \%}$, $D_{50 \%}$, and $D_{2 \%}$ are 57 Gy, 57.5 Gy, 60 Gy, and 63 Gy, respectively. The $D_{\text{mean}}$ for a PRV is also indicated. Notice that the mean absorbed dose for an organ at risk is generally not the same as its median absorbed dose, whereas the mean absorbed dose for the PTV is generally very close to its median absorbed dose.
IMRT reporting for the target

- Minimum dose (D100%) not useful because usually in high gradient areas
- Use D98\% = D_{near-min}
- Also report D_{near-max} = D2\%
- Also report median dose
Reporting for critical structures

- Need to understand anatomy and physiology
- Depends on parallel or serial organ design
- A clinical decision
Normal tissue reporting

- Parallel organs: Need to report multiple DVH points
  - Mean dose typically good as well

- Serial organs: D2% (minimum dose)

- Others: at least three DVH points
Normal tissue reporting

- Parallel organs: Need to report multiple DVH points
  - Mean dose typically good
- Serial organs: D_{2\%} (minimum dose)
- Otherwise at least three DVH points

Important consequence: Outline all of the structure (where ever possible)
Use PTV sub volumes is recommended for plan optimization.

PTV = PTV_{SV-1} + PTV_{SV-2}

Absorbed dose

Volume

PTV_{SV-1}

PTV_{SV-2}

Volume

PTV
ICRU 83 summary

- ICRU report 83 took a long time to develop
- It facilitates discussion between different professions
- It has a lot of useful information and should be consulted prior to implementing IMRT
- It is a logical extension of previous reports
What is different in IMRT

- Radiation Oncologists
- Medical Physicists
- Radiation Therapists

- Contouring, need to commit
- Small fields, QA, data handling
- Better set-up, Image guidance
Local control

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IMRT

IGRT

The aim of radiotherapy
What is different in IMRT

- Radiation Oncologists
- Medical Physicists
- Radiation Therapists
- Patient

- Contouring, need to commit
- Small fields, QA, data handling
- Better set-up, Image guidance
- Better sparing, less toxicity
Intensity Modulated Radiotherapy (IMRT)

A Guide for Commissioners

An NRIG Technology sub-group
- November 2009.

Table 1: Estimate of percentage of radically treated patients likely to benefit from IMRT and consequent proportion of all fractions as IMRT.

<table>
<thead>
<tr>
<th>Tumour site</th>
<th>% of all RT fractions</th>
<th>% pts who benefit</th>
<th>% all fractions as IMRT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Breast</td>
<td>30%</td>
<td>30%</td>
<td>9%</td>
</tr>
<tr>
<td>Prostate</td>
<td>16%</td>
<td>80%</td>
<td>13%</td>
</tr>
<tr>
<td>Gynaecological</td>
<td>5%</td>
<td>20%</td>
<td>1%</td>
</tr>
<tr>
<td>H + N</td>
<td>8%</td>
<td>80%</td>
<td>6%</td>
</tr>
<tr>
<td>CNS</td>
<td>3%</td>
<td>60%</td>
<td>2%</td>
</tr>
<tr>
<td>Other sites</td>
<td>10%</td>
<td>20%</td>
<td>2%</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>24%</strong></td>
</tr>
<tr>
<td><strong>Grand Total</strong></td>
<td></td>
<td></td>
<td><strong>33%</strong></td>
</tr>
</tbody>
</table>
Summary

• IMRT is here to stay
• IMRT is evolving – in principle optimisation is possible for everything such as time, minimising low dose and robustness of delivery
• Multidisciplinary involvement is essential
Think “IMRT”

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• Normal tissue sparing is the key
• Only the computer can tell you how to deliver
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• IMRT requires more work of clinicians (contouring), physicists (commissioning and quality assurance) and RTTs (image guidance)
Thank you