TRAINING COURSE MATERIAL
“TRANSITION FROM 2-D RT TO 3-D CRT AND IMRT”
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20. Treatment verification: imaging and dosimetry
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1. Introduction

Worldwide distribution of cancer types in 2002, ranked by total number of cases (in thousands)


• The American College of Radiation Oncology, Red Book, Guidelines for the ACRO Practice Accreditation Program, 2009.

<table>
<thead>
<tr>
<th>SITE</th>
<th>% Total Cases (ACSNcDB)</th>
<th>Estimated Cases (ACS - 2008)</th>
<th>% XRT AVG</th>
<th>% Cases XRT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head and Neck Sites</td>
<td>3.7%</td>
<td>3.7%</td>
<td>61.3%</td>
<td>2.3%</td>
</tr>
<tr>
<td>Digestive System</td>
<td>17.8%</td>
<td>18.8%</td>
<td>15.5%</td>
<td>2.8%</td>
</tr>
<tr>
<td>Respiratory System</td>
<td>14.1%</td>
<td>16.16%</td>
<td>36.9%</td>
<td>5.2%</td>
</tr>
<tr>
<td>Soft Tissue/Bone</td>
<td>0.9%</td>
<td>0.89%</td>
<td>33.0%</td>
<td>0.3%</td>
</tr>
<tr>
<td>Skin</td>
<td>3.8%</td>
<td>4.71%</td>
<td>1.8%</td>
<td>0.1%</td>
</tr>
<tr>
<td>Breast</td>
<td>17.3%</td>
<td>12.8%</td>
<td>45.6%</td>
<td>7.9%</td>
</tr>
<tr>
<td>Gynecologic</td>
<td>6.1%</td>
<td>8.7%</td>
<td>22.4%</td>
<td>1.4%</td>
</tr>
<tr>
<td>Genitourinary System</td>
<td>19.9%</td>
<td>19.1%</td>
<td>24.5%</td>
<td>4.9%</td>
</tr>
<tr>
<td>Nervous System</td>
<td>3.3%</td>
<td>3.5%</td>
<td>32.4%</td>
<td>1.1%</td>
</tr>
<tr>
<td>Hematologic/Lymphoid System</td>
<td>7.4%</td>
<td>8.3%</td>
<td>8.9%</td>
<td>0.7%</td>
</tr>
<tr>
<td>Other/Unknown</td>
<td>5.7%</td>
<td>3.34%</td>
<td>27.1%</td>
<td>1.5%</td>
</tr>
<tr>
<td>TOTAL</td>
<td>100.00%</td>
<td>100%</td>
<td>28.0%</td>
<td></td>
</tr>
</tbody>
</table>
2. Radiation therapy principles: Clinical indications, outcome and applied radiobiology

Clinical indications and outcome


Fig. 6. Annual incidence of breast cancer in the UK from 1993 to 2000 and the corresponding number of linear accelerators required to treat these with RT based on the actual utilization rate in this indication in Sweden in 2001.


Other material


Applied radiobiology


Other material


3. Altered fractionation

4. Overall QA and review


Other material


5. Equipment selection, acceptance testing, commissioning and QA/QC


FIG. 2. CT-simulator room drawing showing wall lasers and the overhead sagittal laser.


**FIG. 10. Surface and buildup dose for 10_10 cm2 field of a 6 MV beam with various detectors.**
*The actual surface dose is also marked by the arrow.*
Other material


6. Evolution of RT from 2-D to 3-D CRT and IMRT


![IMRT Planning and Delivery Diagram](image-url)


<table>
<thead>
<tr>
<th>Test</th>
<th>Mean</th>
<th>Standard deviation (σ)</th>
<th>Maximum</th>
<th>Minimum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Multitarget</td>
<td>97.8</td>
<td>3.5</td>
<td>99.8</td>
<td>90.8</td>
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<tr>
<td>Prostate</td>
<td>98.6</td>
<td>2.4</td>
<td>100</td>
<td>93.3</td>
</tr>
<tr>
<td>Head and neck</td>
<td>98.1</td>
<td>2.0</td>
<td>100</td>
<td>94.2</td>
</tr>
<tr>
<td>CShape (easier)</td>
<td>97.4</td>
<td>2.8</td>
<td>99.8</td>
<td>93.0</td>
</tr>
<tr>
<td>CShape (harder)</td>
<td>97.5</td>
<td>2.6</td>
<td>99.9</td>
<td>94.0</td>
</tr>
<tr>
<td>Overall combined</td>
<td>97.9</td>
<td>2.5</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Confidence limit = (100 - mean) + 1.96σ = 7σ (i.e., 93.0% passing)

Other material


7. Treatment delivery hardware and software for 3-D CRT


Other material

8. Delivery techniques for IMRT


Other material

• Auj-E-Taqaddas. Investigation of VMAT algorithms and dosimetry. Authorhouse, Bloomington, IN, USA, 2011.

9. Evidence-based medicine and new technology


Other material

10. Patient set-up and immobilisation


![Image of headrests](image)

**FIG. 7.3. Headrests used for patient positioning and immobilization in external beam radiotherapy**


![Image of on target guide](image)


![Image of video cover](image)
Other material


- Faiz M. Khan, Treatment Planning in Radiation Oncology, second edition, Lippincott Williams & Wilkins, 2006.
11. Imaging for target volume and organ at risk determination


  \textit{Figure 3.5b. T0.10 Leeds test object – fluoroscopic image.}

FIG. 6. A quality assurance phantom for three-dimensional radiation treatment planning.


**Other material**


• EMERALD project (http://www.emerald2.eu)
12. Definition of target volumes and organs at risk


Other material


13. Contouring and prescribing for specific clinical sites for 3-D CRT (and IMRT)


Other material


• Brachial Plexus Contouring Atlas (http://rtog.org/atlases/BrachialAtlas/Brachial%20plexus%20contouring.pdf)


• Pelvic Lymph Node Volumes for Prostate Cancer Atlas (http://rtog.org/Atlases//PelvicLymphNodeProstateAtlas/Pel%20LN%20Vol%20Prostate.ppt)


• ESTRO-FALCON: Multifunctional platform for contouring and delineation (http://www.estro-education.org/elearning/Pages/Falcon.aspx)

• ESTRO-TIGER: Tutorial for Image Guided External Radiotherapy (http://www.estro-education.org/elearning/Pages/TIGER.aspx)
14. Geometric uncertainties


Other material

15. Treatment planning 2-D RT to 3-D CRT

Other material


16. Treatment planning 3-D CRT to IMRT

(http://www.medicalphysics.org/apps/medicalphysicsedit/VANDYKCH08.pdf)

(http://www.aapm.org/pubs/reports/RPT_81.pdf)

FIG. 4. CT images of a patient with a hip prosthesis —cup, head, and stem!: —a! frontal image/scout, —b! lateral view scout, —c! transversal slice showing artifacts, and —d! same image as in —c!, but contrast level adjusted to better visualize the contour of the prosthesis.
(http://www.aapm.org/pubs/reports/RPT_85.pdf)

Figure 27. Correction factor for a 15 MV x-rays, 5 ¥ 5 cm² field as a function of depth below the surface of the phantom for densities of 0.015 (humid air) and 0.18 and 0.31 (lung) g cm⁻³.

(http://www.estro-education.org/publications/Pages/ESTROPhysicsBooklets.aspx)

(http://www-naweb.iaea.org/nahu/dmrp/pdf_files/ToC.pdf)


FIG. 11. Opposed, oblique field treatment plan (15 MV photons) showing the 100% isodose coverage for MC (modified DPM, University of Michigan/UMPlan) in the solid line, and an equivalent path length (EPL, University of Michigan/UMPlan) algorithm in the dashed line. The PTV is demarcated in white.

Other material

• Faiz M. Khan, Treatment Planning in Radiation Oncology, second edition, Lippincott Williams & Wilkins, 2006.


17. Plan evaluation for 3-D CRT and IMRT


**Other material**


18. Additional physics equipment QA for IMRT


Other material

19. Patient specific physics QA for IMRT


Other material

20. Treatment verification: imaging and dosimetry


Figure 5. Schematic diagrams for entrance (a) and exit (b) dose calibration factors.


Figure II.1: Schematic representation of the different doses involved in in vivo dosimetry for a single beam.


Figure I-C-2. Schematic illustration of a typical treatment process using in-room radiographic imaging.


Other material


21. Special treatment techniques

Total body irradiation (TBI), half body irradiation (HBI), total marrow irradiation (TMI), total lymphoid irradiation (TLI)


Other material


Stereotactic radiosurgery (SRS), stereotactic radiotherapy (SRT), stereotactic body radiotherapy (SBRT)


| Table 1: Comparison of typical characteristics of 3D/IMRT radiotherapy and SBRT. |
|-----------------|-----------------|-----------------|
| Characteristic   | 3D/IMRT         | SBRT            |
| Dose/fraction   | 1.8-3 Gy        | 6-36 Gy         |
| No. of fractions| 10-20           | 1-3             |
| Target definition| CTV/PTV (gross disease+clinical extension) | CTV/PTV (well-defined tumors) |
| Margin           | Centimeters     | Millimeters     |
| Physical/dosimetry monitoring | Direct | Direct |
| Required setup accuracy | TG44, TG42 | TG44, TG42 |
| Primary imaging modality for treatment planning | CT | Multimodality: CT/IRM/PET/CT |
| Daily radiation in geometric verification | No | Yes |
| Maintenance of high spatial targeting accuracy for the entire treatment | Moderately enforced | Strictly enforced (ultra-precise immobilization and high frequency position monitoring) |
| Need for respiratory motion management | Moderate—must be at least considered | Highest |
| Staff training | Highest | Highest |
| Technology implementation | Highest | Highest |
| Radiobiological understanding | Moderately well understood | Poorly understood |
| Interaction with systemic therapies | Yes | Yes |

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**Intra-operative radiotherapy (IORT)**


FIG. 1. The soft-docking system used by the Mobetron. (a) The electron applicator, in contact with the tumor bed, is rigidly clamped to the surgical bed using a modified Bookwalter clamp. (b) The gantry being moved for soft docking to the applicator. (c) The LED display and electron applicator. The green light in the center of the display indicates that proper alignment has occurred and the gantry is properly docked. Note the air gap (4 cm ± 1 mm) between the end of the gantry and the top surface of the applicator.

Other material

Total skin electron irradiation (TSEI)

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