- Introduction
- Delivery techniques
- Planning steps, Tumor vol delineation
- Clinical studies
- Advantages, Pit falls
3D-Conformal Radiation Therapy

3D-CRT

• Radiation intensity is uniform within each beam
• Modulation conferred only by wedges.
Intensity Modulated Radio Therapy

Conformal Radiation Therapy with Non-uniform intensity distributions generated via Inverse planning by a computer optimization process.

“Intensity of Radiation is modulated”
How does IMRT work

Each field is subdivided into numerous “beamlets” whose intensities are individually modulated to achieve a nonuniform dose contribution from each field.
Beamlet modulation is accomplished by actively moving multiple leaves during radiation treatment thus achieving the desired dose distribution throughout the tissue volume.
How does I M R T work

- 10 x 10 cm port is divided into 1 cm² beamlets
- There are now $10^2$ beams in the port
- Each can have an intensity weight of 0 – 100%
- Then we have $10^{200}$ possibilities
- If we use 5 ports we have $10^{1000}$ possibilities
Inverse Planning

- We need to optimize Beam location, energy, modality
- High speed computer tests all the possibilities of a human decision for a best possible solution
- The mathematical process of defining a solution is known as “Inverse planning”
Computer Optimization

- **Forward Planning:**
  
The beam geometry i.e. beam angle, shape, modifier, weights etc. is first defined, followed by calculation of the 3D dose distribution.

- **Inverse Planning:**
  
  the computer then adjusts the beam parameters to achieve the desired outcome.
Primary advantage of this technology

- *Treating target volumes adjacent to critical or sensitive normal tissues*
- *Delivery of therapeutic radiation doses to target*
- *Minimizing normal tissue toxicity.*
**IMRT delivery techniques**

1. **Slit MLC:**
   - Narrow rectangular slit MLC
   - Rotates in an arc around the patient
   - Treats a target vol with multiple thin slices.

2. **Tomotherapy:**
   - Actively modulated narrow slit beams
   - as the treatment gantry and MLC rotate
   - pt moves through gantry ring on a couch.
IGRT

Tomotherapy
IMRT delivery techniques

Standard MLC:

Beams can be delivered via multiple fixed gantry positions with a standard MLC

3. ‘Step and shoot’

- Delivers Sequential subfields with
- Individualized intensity distributions from each gantry position,
- Radiation beam off between subfields.

4. Dynamic mode

- MLCs move while radiation beam is on
5. *Intensity modulated Arc therapy (IMAT)* combining rotational arcs with dynamic multileaf collimation.

6. *Fully dynamic systems* MLC, gantry, and treatment couch all move independently at some point during beam delivery.
Rationale of IMRT in H & N Cancer

1. Anatomically complex H&N region - an ideal option - IMRT.

2. Lack of organ motion in the H&N region - an ideal region for IMRT.

3. Allows for dose escalation - concomitant boost – ideal for H&N
IMRT Sites in H&N

- Nasopharynx
- Sinonasal region
- Parotid gland
- Tonsil
- Buccal mucosa, Gingiva
- Thyroid
- Tumor tracking along the cranial nerves.

- Based on the studies comparing IMRT and other treatment approaches.
Steps of IMRT

- Clinical evaluation & assessment
- Simulation
- Planning CT/MRI/PET-CT scan
- Target vol Delineation GTV, CTV, PTV
- IMRT Planning, Dose Vol Histogram
- QA
- Execution of IMRT
Steps of IMRT in H&N Cancer

Clinical Assessment

- *Pt is seen by Surgeon, RO, MO*
- *Examination of the H&N region*
  - *Indirect laryngoscopy*
  - *Fiberoptic nasopharyngolaryngoscopy*
  - *An illustration of the physical findings*
  - *Demonstrating the primary tumor extent*
  - *Lymph-adenopathy*
Steps of IMRT in H&N Ca …

Clinical Assessment…

• Pretreatment dental consultation
  • Extraction of bad teeth
  • Initiation of prophylactic fluoride therapy.
• Pretreatment ophthalmology and audiology consults
• Thyroid function tests baseline.
• Review of imaging studies and further workup
Simulation/CT simulation in the treatment position

- Conventional simulation followed by a CT or
- CT Simulation.
SIMULATION
Neck hyper-extended using a head rest.
SIMULATION

Immobilization in supine position with custom thermoplastic mold
• Shoulder traction to minimize shoulder in RT fields
• Palpable masses & incisional scars are outlined by ...
• For CT, use iv contrast to diff vessels from masses or LN
It is imperative that the radiation oncologist be trained in the interpretation of all images used for structure localization.
PET Scores over others!

CT, MRI
Anatomical imaging

PET
is functional imaging
Active viable tumor
Limitations of Anatomical Imaging

- Tumor and normal tissue have similar density or intensity
- Tumor and normal tissue have similar properties of contrast enhancement
Advantages of Biological Imaging...

Will not be affected with post op anatomical disturbances!
Clinical applications of FDG-PET in Target volume delineation...

- Lung Cancer
- Head and Neck Cancer
- Gynecological Cancers
- GI tract Cancers
- Brain tumors
- Lymphomas
# Impact of PET-CT in H & N Cancer

<table>
<thead>
<tr>
<th>Author</th>
<th>Patients</th>
<th>Change of GTV using PET</th>
<th>Increase in GTV</th>
<th>Decrease in GTV</th>
<th>Remarks</th>
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<tr>
<td>Rahn, 1998</td>
<td>22 (prim)</td>
<td>41%</td>
<td>41%</td>
<td>0%</td>
<td>No image fusion</td>
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<tr>
<td></td>
<td>12 (recur)</td>
<td>58%</td>
<td>58%</td>
<td>0%</td>
<td></td>
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<tr>
<td>Nishioka, 2002</td>
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<td>0%</td>
<td>71%</td>
<td>PET/CT/MRI fusion</td>
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<tr>
<td>Ciernik, 2003</td>
<td>12</td>
<td>50%</td>
<td>17%</td>
<td>33%</td>
<td>Integrated PET-CT</td>
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<tr>
<td>Daisne, 2004</td>
<td>29</td>
<td>93%</td>
<td>18%</td>
<td>75%</td>
<td>CT-PET image fusion</td>
</tr>
<tr>
<td>Paulino, 2005</td>
<td>40</td>
<td>100%</td>
<td>-</td>
<td>-</td>
<td>PET/CT/MRI and surgical specimen image fusion</td>
</tr>
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</table>
Ca Nasopharynx
IMRT - Target volume

- IMRT requires a thorough understanding of target delineation in the complex H&N
- Areas to be delineated on the planning CT
  - Gross tumor volume (GTV)
  - Subclinical disease (CTV)
Target volumes

- **Gross tumor volume GTV (Primary & LN)**
- **Clinical Target volume CTV**
  - Primary incl subclinical + elective nodal regions
- **Planning Target volume (gross)**
  - 1 cm margin everywhere
  - except post along the skull (0.5 cm margin)
- **Planning Target volume PTV (elective)**
  - Uniform .5 cm margin all round
Target volume(s) should follow the recommendations of ICRU Reports 50 and 62.
Clinical Target Volume (CTV)

- targeting the sub-clinical disease

- Every primary in H&N region there are associated LN regions or levels, that are at risk & must be contoured.

- Knowledge of these levels and their anatomic boundaries is essential.

- The RTOG, EORTC and DAHANCA groups have all established CTV guidelines for the clinically and radiographically negative, surgically nonviolated neck - imaging based nodal atlases
CT-based delineation of lymph node levels and related CTVs in the node-negative neck: DAHANCA, EORTC, GORTEC, NCIC, RTOG consensus guidelines

Steps…

*Dose volume histograms (DVHs)*

Accurate calculation of DVHs

*Biological indices (e.g., normal tissue complication probability)*

*Mandate the inclusion of the entire extent of the relevant structures*
Normal tissues Contouring…

- Parotid glands
- Spinal cord
- Brainstem
- Cochlea
- Optical structures
- Pituitary gland
Nasopharyngeal Ca

- PTV
- CTV
- GTV
Nasopharyngeal Ca
Nasopharyngeal Ca
Nasopharyngeal Ca
Nasopharyngeal Ca
Sinonasal Ca
Ca Oral Tongue
Post-op/RT
Recurrence
Ca Oral Tongue
Post-op/RT
Recurrence
Ca Rt Tonsil
Ca Lt Buccal Mucosa
Post-op/RT
Recurrence
Ca Lt Buccal Mucosa
Post-op/RT
Recurrence
Discussion with Physicist..

Communicating pertinent information

- Brief clinical findings
- Location of the primary
- Adenopathy
- High risk regions
- Adjacent critical structures
IMRT - Ca Oropharynx
IMRT
Head & Neck studies
### Table 1. Locoregional Control After IMRT for Head and Neck Cancer

<table>
<thead>
<tr>
<th>Study</th>
<th>No. of Patients</th>
<th>Primary Site</th>
<th>RT</th>
<th>Follow-Up (months)</th>
<th>Control</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>Definitive</td>
<td>Postoperative</td>
<td>Median</td>
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<tr>
<td>Chao et al⁹</td>
<td>126</td>
<td>Various</td>
<td>52</td>
<td>74</td>
<td>26</td>
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<tr>
<td>Lee et al⁵</td>
<td>67</td>
<td>NPX</td>
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<td>0</td>
<td>31</td>
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<tr>
<td>Chao et al⁰</td>
<td>74</td>
<td>OPX</td>
<td>31</td>
<td>43</td>
<td>33</td>
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<tr>
<td>Eisbruch et al²¹</td>
<td>133</td>
<td>Various, non-NPX</td>
<td>60</td>
<td>73</td>
<td>32</td>
</tr>
<tr>
<td>Kam et al³³</td>
<td>63</td>
<td>NPX</td>
<td>63</td>
<td>0</td>
<td>29</td>
</tr>
<tr>
<td>Kwong et al³⁴</td>
<td>33</td>
<td>NPX</td>
<td>33</td>
<td>0</td>
<td>29</td>
</tr>
</tbody>
</table>

Abbreviations: IMRT, intensity-modulated radiotherapy; RT, radiotherapy; NPX, nasopharynx; OPX, oropharynx.

*Patients treated from 1994 to 2002; three-dimensional conformal radiotherapy was used before 1996, and IMRT thereafter.*
<table>
<thead>
<tr>
<th>Center</th>
<th>N</th>
<th>Stage</th>
<th>FU (mo)</th>
<th>LC</th>
<th>DM-Free</th>
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<tr>
<td>Bucci</td>
<td>118</td>
<td>50% T3-4</td>
<td>30</td>
<td>96%</td>
<td>72%</td>
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<tr>
<td>IJROBP, 2004</td>
<td></td>
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<td></td>
<td>(4-year data)</td>
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<tr>
<td>Kam</td>
<td>63</td>
<td>51% T3-4</td>
<td>29</td>
<td>92%</td>
<td>79%</td>
</tr>
<tr>
<td>IJROBP, 2004</td>
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<td></td>
<td>(3-year data)</td>
</tr>
<tr>
<td>Wolden</td>
<td>74</td>
<td>51% T3-4</td>
<td>35</td>
<td>91%</td>
<td>78%</td>
</tr>
<tr>
<td>IJROBP, 2006</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(3-year data)</td>
</tr>
</tbody>
</table>
IMRT for NPC
RTOG Protocol H-0225 (Lee & Garden)

Stage: I-IVb
Histology: WHO I-III

**IMRT:**
- 2.12 Gy/F/d X 33 F
to $\geq$ 95% of GTV
- 1.8 Gy/F/d X 33 F
to $\geq$ 95% of CTV

Chemotherapy ($\geq$T2b or N+):
- Concurrent: Cisplatin x 3
- Adjuvant: Cisplatin + 5-FU
IMRT for Oropharyngeal SCC
RTOG Protocol H-0022 (Eisbruch & Chao)

Stage: T1-2 N-1
Site: Tonsil, BOT, Soft Palate

Gross disease PTV:
66 Gy/30 FX

Subclinical disease PTV:
54-60 Gy/30 FX

Boost of 4-6 Gy/2-3 FX to the tumor PTV allowed
RTOG 0022 – ASTRO 2006

- Study population: 67 patients (14 centers)
- Tumor: tongue base-20 (39%), tonsil-33 (49%), soft palate 8 (12%)
- Stage: T1-25%, T2-75%; N0-57%, N1-43%
- Median follow-up: 1.6 (0.2-3.8) years
- LR progression: 3 patients (4.9%)
- No metastatic disease observed

A Eisbruch, J Harris, A Garden, C Chao, W Straube, C Schultz, G Sanguineti, C Jones, W Bosch, K Ang
IMRT for Oropharynx Cancer

- 2000-June 2003: 133 patients
- Age: 30-75 (53) years; 85% male
- Site: tonsil-52%; tongue base-40%
- T1-2(x): 114; T3-4: 19
- Chemotherapy: 28 (T3-4 or N2-3)
- 3-Y local control: 95%
- 3-Y overall survival: 93%

Garden et al., 2005
Recovery of Saliva Flow (A vs C)

Kam et al., ASCO 2005 (NPC)

Fractional Change in Parotid Flow-rate vs Time Post Irradiation

Ratio of post RT / pre-RT Parotid outflow

IMRT
Non-IMRT

p < 0.0001 0.0001 0.0001

Time Post RT
Advantages – Variable doses

- **Boosting doses within targets**
  Diff doses per fraction to multiple target vol within a treatment field.

- **Simultaneous Integrated Boost**
  Concomitantly with standard doses to the remainder of targets

- **70Gy vs 45-55Gy within the target vol**
Advantages of IMRT...

Eliminate the need for standard fields

- Low anterior neck field.
- Electron boost
Advantages of I M R T...

Re-treatment

Re-treatment of radiated H&N ca
Possible due to its ability to spare
adjacent normal tissues with
acceptable target dose uniformity.
Sparing of normal tissues

Uninvolved tissue sparing of multiple sites to reduce short and long term side effects

- Major and minor salivary glands, most notably parotids, mandible, oral cavity, larynx and pharynx.

- Critical structures - Cochlea, temporal lobes, optic pathways, spinal cord, brainstem & brain
Pit falls ....

- Smaller PTV margins, Sharper dose fall-off can allow for geographic misses if target localization and immobilization are not accurate
- More complex, more beams/arc increase the overall treatment time - decrease dose rate!
- Lack of uniformity – no IMRT planning standards for every anatomical site.
- Diff to compare data between institutions
Changes in Anatomy during course of Rx

Planning CT

Three Weeks into RT

Barker et al. *IJROBP* 59:960, 2004 & Lei Dong et al. (MDACC)
Dosimetric Impact of Anatomic Changes

Original Plan

Four Weeks Later (Mapped back to the original planning CT using deformable registration)

Barker et al. IJROBP 59:960, 2004 & Lei Dong et al. (MDACC)
Conclusion

- IMRT is an obvious choice for H&N Ca (NP, OP, PNS etc)
- Obtains tight dose gradients around gross & sub-clinical disease when desirable
- Tumor in close vicinity of the cord, parotids & brain stem
- Re-irradiation possible
- **Requires expertise**
- Newer tech-needs longer f u to testify its advantage
Lecture, lecture, lecture …

Audience
Many Thanks

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Apollo Cancer Hospital, Hyd