Stereotactic Body Radiation Therapy
Quality Assurance
Educational Session

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SBRT fundamentals

- Extra-cranial treatments
- Single or small number (2-5) of fractions
- Stereotactic immobilization
- Image guidance
- Control of organ motion

Outline

- Published guidelines
  - ASTRO / ACR
- AAPM Task Group 101 report
- UC Davis experience
  - Commissioning
  - Ongoing QA
- UC Davis FMEA of SBRT delivery
ASTRO / ACR guidelines (2010)

- Qualifications and roles of personnel
- Quality control / safety
- Simulation and treatment


ASTRO / ACR guidelines (2010)

- Generic / formulaic
- Somewhat nonspecific
- Lacks the word “recommend”

AAPM Task Group 101 (2010)

- Comprehensive, readable report (24 pages, 24 authors), Benedict et al Medical Physics, Vol. 37, No. 8, August 2010

- Distinguishing features 3D CRT – SBRT
  - Increased number of beams
  - Non-coplanar beams
  - Small or no margins for penumbra
  - Inhomogeneous dose distribution
• Patient selection
  – SBRT is still developing
  – Patients should be treated either on or according to NCI (RTOG) or similar protocols
  – Ensures strict guidelines for volumes, prescriptions etc, developed by leaders in the field are followed
  – Clinical trials should be employed for new indications

AAPM Task Group 101 - Recommendations

• Simulation and imaging
  – Guidelines including length of scan and slice thickness
  – Ensure target and organ at risk coverage, 1 – 3 mm slices
  – \textsuperscript{18}F-FDG PET for enhanced specificity and sensitivity, useful for staging
  – Resolution limit of PET

AAPM Task Group 101 - Recommendations

• Treatment planning
  – Very high local control – GTV and CTV are identical
  – ITV and PTV concepts
    • PTV margin 5mm radial and 1cm sup / inf
  – With 4D CT sup / inf margin reduced to 5mm
• Calculation grid size
  – Published IMRT data shows a 2.5mm grid gives 1% accuracy in high dose gradients
  – 4mm grid c.f. 1.5mm grid gives 5.6% difference for prescribed dose
  – Use 2mm grid for SBRT calculations

• Heterogeneity correction
  – Convolution / superposition accounts for recoil electron transport
  – Radiological Physics Center thorax phantom and RTOG 0236
  – Pencil beam algorithms not recommended

Acceptance testing, commissioning and quality assurance

  End to end test
  Winston Lutz test
  CBCT stability
  MLC accuracy
UC Davis experience as example

- Background
- Commissioning experience
- Ongoing (patient specific) QA

Commissioning SBRT at UC Davis

- Digital Winston Lutz test
- Fitting volunteers in SBRT frame
- Phantom (end to end) studies
  - RPC lung phantom
Digital Winston Lutz test
  – four cardinal gantry angles, collimator 0 and 90

Commissioning SBRT at UC Davis
  – Digital Winston Lutz test
  – Fitting volunteers in SBRT frame
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    • RPC lung phantom
Commissioning SBRT at UC Davis

- Digital Winston Lutz test
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Radiological Physics Center, MD Anderson
Anthropomorphic phantom
RTOG lung trial credentialing
Phantom loaded with detectors
Scan, plan, treat, return for readout
UC Davis SBRT practice

• Linac based – Elekta platform
  – Static non-coplanar
  – Limited number of IMRT plans
UC Davis SBRT practice

- Stereotactic frame – abdominal compression

UC Davis SBRT practice

- Heterogeneity correction
- Pinnacle planning system v.9.0
UC Davis SBRT practice

- Fluoroscopy to evaluate diaphragm motion
- Cone Beam CT for on set alignment

Kilovoltage PlanarView images (XVi)
UC Davis patient specific QA processes

- Patient specific QA
  - Physics check of co-registration 4D CT
  - Plan review / chart rounds
  - Patient dry run
  - Map check and Quasar delivery QA
  - Daily diaphragm motion view and cone beam CT
  - Procedural pause / time out
  - Physics presence throughout delivery

<table>
<thead>
<tr>
<th>Energy (MV)</th>
<th>Dose (cGy)</th>
<th>Lung (cc)</th>
<th># of fields</th>
<th>45Gy (min)</th>
<th>90% (min)</th>
<th>50% (min)</th>
<th>V20 (max)</th>
<th>Heart (max)</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>1250</td>
<td>16.83</td>
<td>8</td>
<td>95.0%</td>
<td>76.20</td>
<td>99.7%</td>
<td>2.00%</td>
<td>18.5 Gy</td>
</tr>
</tbody>
</table>

Dose constraints:
- Spinal cord max < 22Gy, < 0.35cc < 18Gy
- Esophagus < 5cc to 15Gy, max < 25Gy
- Lung V20 < 10%, < 1500cc < 11.6Gy
- Heart Max < 30Gy, < 15cc to 26Gy
- Central airways Max < 30Gy, < 4cc to 15Gy

Patient dry run
Failure Modes and Effects Analysis Intro:

- Process started by department interacting with hospital with QA committee
- One analysis per year
- Disciplines
  - Radiation oncologist, physicist, dosimetrist, therapist, clinical engineer, QA committee members (nurse managers)

Failure Modes and Effects Analysis Process:

- Step by step breakdown of patient flow from every team member
- Overlap of responsibilities
  - Develop flow chart (modes)
Process:
• 28 steps for treatment
• Turn process chart into failure modes
• What do we do at this point
  – What could go wrong?
  – That could never happen?
  – But what if?

Failure modes:
• For each step in the process at least one potential failure was derived
• Three factors were associated with each mode
• Probability – detectability – severity
• Score 1 – 10 for each factor

Probability:
• Likelihood of occurrence
  – Score 1 for event happening to 1% of patients
  – Score 10 for every patient
**Detectability:**
- How likely are we to catch the failure
  - Score 1 for very easy to catch
  - Score 10 for almost impossible

<table>
<thead>
<tr>
<th>Probability</th>
<th>Detectability</th>
<th>Severity</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 – 2</td>
<td>Very easy</td>
<td>No dosimetric effect</td>
</tr>
<tr>
<td>3 – 4</td>
<td>Human error</td>
<td>5% dose difference</td>
</tr>
<tr>
<td>5</td>
<td>Lucky catch</td>
<td>10% dose difference</td>
</tr>
<tr>
<td>6 – 8</td>
<td>Very difficult</td>
<td>Reportable, 20% difference</td>
</tr>
<tr>
<td>9 – 10</td>
<td>Almost impossible</td>
<td>Reportable, injury / death</td>
</tr>
</tbody>
</table>

**Severity:**
- The consequences of the failure reaching the patient
  - Score 1 for no dosimetric effect, may cause discomfort or inconvenience
  - Score 10 for reportable event, 20% or greater dose difference, injury or death
Risk probability number (RPN):

- Multiply three scores
  - Probability x detectability x severity
- Example – misalignment of CBCT iso
  - Probability = 1
  - Likelihood of detection = 6
  - Severity = 10
  - RPN = 1 x 6 x 10 = 60

Results:

- Choose the highest RPN’s and change clinical practice
  - Law of diminishing returns

Results, UC Davis:

- Change in practice / planning technique
  - Prior to FMEA couch translations were required to fold imaging panels
  - Risk of invalidating CBCT alignment
Folding IGRT panels to allow non coplanar beams

Results, UC Davis:

• Change in practice / planning technique
  – After FMEA we devised a method of planning and rotating the couch to reduce this risk
  – Lower RPN
  – No couch translations after CBCT correction

Laser marking after CBCT shift is final and checked when couch is rotated for non coplanar beams
Results, UC Davis:

- Safety measures
  - Checklist and surgical timeout
  - MD sign off on CBCT
  - Therapist sign off on
    - Patient identity
    - CBCT shifts

Conclusion:

- FMEA is time consuming and human resource intensive
  - 100 man hours
- Valuable exercise
  - Change in technique
  - Unified protocol
  - Safety conscious

Conclusion:

- FMEA process is generic but the results are somewhat clinic specific
  - Specific to equipment
  - Workload
• Highly effective ablative doses
• Continuously evolving field
  – IMRT and VMAT delivery methods already common
  – Single fraction treatments
  – 4D CBCT

Thank you