TPS Commissioning and QA: A Process Orientation & Application of Control Charts

Michael B Sharpe, PhD
Radiation Medicine Program
DISCLOSURE

- Customer, collaborator, licensing:
  - Elekta AB, Raysearch Laboratories AB, MODUS Medical Devices
- Leadership position:
  - Cancer Care Ontario

ACKNOWLEDGEMENTS

- Tim Craig, Jean-Pierre Bissonnette, Stephen Breen, David Jaffray, Daniel Letourneau, BeiBei Zhang, Stuart Rose, Gavin Disney,
- Miller MacPherson, Katharina Sixel,
- Jake Van Dyk, Jerry Battista, Benedict Fraas

- Anything I say might be superseded by next two speakers
Objectives

- Introduction & Review
- Acceptance & Commissioning
- Periodic Quality Assurance
- “New” Definition of Quality
- Quality Tools

- Highlight the current reference documents; summarize key aspects

**FOCUS:**
- Configure and assure TPS is ready *clinical integration.*

- Scope does not include:
  - Staff orientation/training
  - Development and documentation of clinical procedures
Acceptance & Commissioning

Organizational Choices

**Systems**
- Support:
  - Immobilization measurement devices
  - 2nd dose calculation
  - Documentation
  - Communication
- Treatment units
- ROIS
- TPS
- Imaging

**Protocol**
- Plans are reviewed
- Developed & documented by collaboration and peer-review
- Maintain procedures & criteria to plan + deliver appropriate treatments.

**Infrastructure**

**Patient**
References

- AAPM TG 53 (Report 62):

- AAPM TG 62 (Report 85)
  - Tissue Inhomogeneity Corrections For Megavoltage Photon Beams (2004)

- IAEA Technical Reports Series No. 430

- AAPM TG 119:
  - IMRT planning and QA test data via aapm.org

- IAEA Technical Document 1540

- IAEA Technical Doc. 1583
## Commissioning

**AAPM Task Group 53**

<table>
<thead>
<tr>
<th>Task Group</th>
<th>Topic</th>
<th>Inception</th>
<th>Completed</th>
<th>Report</th>
</tr>
</thead>
<tbody>
<tr>
<td>65</td>
<td>Tissue Heterogeneities in Photon Beams</td>
<td></td>
<td>2004</td>
<td>85</td>
</tr>
<tr>
<td>66</td>
<td>CT Simulators</td>
<td></td>
<td>2003</td>
<td>83</td>
</tr>
<tr>
<td>71</td>
<td>MU Calculations</td>
<td></td>
<td>2014</td>
<td>258</td>
</tr>
<tr>
<td>100</td>
<td>QA – Evaluate Needs</td>
<td></td>
<td>2003</td>
<td></td>
</tr>
<tr>
<td>105</td>
<td>Monte Carlo Clinical Implementation</td>
<td></td>
<td>2007</td>
<td></td>
</tr>
<tr>
<td>106</td>
<td>Accelerator Commissioning</td>
<td></td>
<td>2008</td>
<td></td>
</tr>
<tr>
<td>114</td>
<td>MU Calculations (non-IMRT)</td>
<td></td>
<td>2011</td>
<td></td>
</tr>
<tr>
<td>117</td>
<td>MRI – In SRS Treatment Planning</td>
<td></td>
<td>2005</td>
<td></td>
</tr>
<tr>
<td>119</td>
<td>IMRT - Commissioning</td>
<td></td>
<td>2009</td>
<td></td>
</tr>
<tr>
<td>120</td>
<td>IMRT - Tools &amp; Techniques</td>
<td></td>
<td>2011</td>
<td></td>
</tr>
<tr>
<td>132</td>
<td>Image Registration</td>
<td></td>
<td>2006</td>
<td></td>
</tr>
<tr>
<td>145</td>
<td>PET - Quantitation</td>
<td></td>
<td>2006</td>
<td></td>
</tr>
<tr>
<td>155</td>
<td>Dosimetry – Small Fields</td>
<td></td>
<td>2007</td>
<td></td>
</tr>
<tr>
<td>157</td>
<td>TPS – Monte Carlo Commissioning</td>
<td></td>
<td>2007</td>
<td></td>
</tr>
<tr>
<td>163</td>
<td>IT - Disaster Preparedness</td>
<td></td>
<td>2007</td>
<td></td>
</tr>
<tr>
<td>166</td>
<td>Use and QA of Biological Models</td>
<td></td>
<td>2012</td>
<td></td>
</tr>
<tr>
<td>174</td>
<td>PET - Monitoring</td>
<td></td>
<td>2008</td>
<td></td>
</tr>
<tr>
<td>189</td>
<td>MRI - DCE</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
AAPM TG53  Responsibilities – Vendors, Users

- Specification, Design, Management
  - Best practices, policies - e.g. SLA, Security, Redundancy
- Service Contract
- Documentation & Training
- Software validation (safety, QA)
- Communication (bugs, risks, feature enhancements)

- Related relationships
  - Vendor
  - IT personnel
  - Administration
  - Therapists/Planners, Physicians
Acceptance

TPS Operation Standards

- Format of displays, units, date & time
- Data limits, transfer
- Saving and archiving data
- Equipment and source model
- Patient model
- Treatment planning
- Dose calculation
- Documentation - Treatment plan report

“The consultants recommend that the procedure for acceptance testing of treatment planning systems should be made more similar to that of other equipment used in a radiotherapy department. After installation of a planning system in a hospital, the vendor should perform a series of tests, together with the user, to demonstrate that the system performs according to its specifications…”
Commissioning

- Qualified medical physicist readies system for stable & routine clinical use.
- TPS models and interacts with devices used for imaging and treatment.
  - Document & configure geometric, functional information.
  - Collect internally consistent data (CT#, dose distributions)
  - Configure interfaces to devices & ROIS.
- Validate availability and proper function of features (per vendor specifications, clinical requirements).
Technology Advances
Our collective thinking evolves

- Many other AAPM Guidelines
Coordinates, Movements & Scales

- Movements, scales, limits, accessories.
- Allowed mechanical movements, speeds, limits.
- Identification (coding) of machines, modalities, beams (energies) & accessories (linking of TPS, ROIS and Machine).
- Should be understood and configured prior to commissioning dose algorithms - Requires careful verification.
- Effort is often taken for granted.
- Mistakes could cause systematic errors.
- IEC 61217, 60601

Tissue Density Calibration

For dose computation, derive high-energy radiation interaction properties of materials from CT Images - Hounsfield Units:

\[ HU = 1000 \left( \frac{\mu - \mu_w}{\mu_w} \right) \]

Nohbah A et al, JACMP, 12(3) (2011)
Images Support Dose Calculations

CT density

μ/ρ lookup table

Figure 2-20  The relative importance of the three major types of gamma-ray interaction. The lines show the values of $Z$ and $h\nu$ for which the two neighboring effects are just equal. (From The Atomic Nucleus by R. D. Evans. Copyright 1955 by the McGraw-Hill Book Company. Used with permission.)
Tissue Density Calibration

Error depends on dose gradient, attenuation estimate, path length

\[ \Delta D = -S \Delta \mu \Delta l \]

\( S \) - dose gradient
\( \Delta \mu \) - attenuation variation
\( \Delta l \) - spatial extent

With thanks to Robert Weersink, PhD
Tissue Density Calibration

- Derived high-energy radiation coefficients may occasionally be in error by 10% (e.g. bone & low kVp)
- The uncertainty in the dose distribution due to these errors is <1% for photon; 2%/2mm for electrons.
- 8% to 10% CT# error leads to less than 1% dose error.
  - Thomas SJ, BJR. 72 781-786 (1999)
  - Nohbah A et al, JACMP, 12(3) (2011)
Why are CT numbers a good way to estimate radiological properties of tissue?

A. We get to see inside the patient!
B. The angular momentum of the dipole distribution is similar.
C. The power to weight ratio is ideal.
D. In water-like materials, attenuation is dominated by the Compton Effect over the pertinent range of photon energies, creating a direct estimate of electron density.
E. None are true
Why are CT numbers a good way to estimate radiological properties of tissue?

A. We get to see inside the patient!

B. The angular momentum of the dipole distribution is similar.

C. The power to weight ratio is ideal.

D. In water-like materials, attenuation is dominated by the Compton Effect over the pertinent range of photon energies, creating a direct estimate of electron density.

E. None are true

Regarding tolerances for relationship between CT numbers to tissue density, which of the following is TRUE?

A. It must be monitored closely and carefully
B. An 8% error in estimating tissue density will cause a 1% dose error
C. A 1% error in estimating tissue density will cause an 8% dose error
D. Electron dose distributions are not sensitive to CT numbers
E. All are true.
Regarding tolerances for relationship between CT numbers to tissue density, which of the following is TRUE?

A. It must be monitored closely and carefully
B. An 8% error in estimating tissue density will cause a 1% dose error
C. A 1% error in estimating tissue density will cause an 8% dose error
D. Electron dose distributions are not sensitive to CT numbers
E. All are true.

AAPM Task Group 53

Non-Dosimetric

Positioning & immobilization
Image acquisition (all sources)
Anatomical description
  • Dataset registration
Beams

Operational aspects of dose calculations

Plan evaluation
Documentation (HCO)
Plan implementation & verification (ROIS)
  • Coordinates & Scales
    • Data transfer
    • Reference Images

Dosimetric

Consistent measurements
Data input into the RTP system
Dose model parameters
Methods for comparison & verification
Verify Calculations
Absolute dose & plan normalization
Clinical verifications

AAPM Task Group 53
Beam Modeling

Parameters

- Head/collimator geometry
- Energy Spectrum
- Fluence profile
- Collimator transmission
- Focal spot (penumbra)
- Extra-focal contribution
- Electron contamination
- Reference Dose Rate
- Measured Output Factors

Adjustment to model parameters to fit non-clinical beams
TPS calculations, at discrete points, are compared with measured profiles and depth-dose curves.

TPS will give a reproducible deviation from the measured value at certain points within the beam.

IAEA TRS430 provides detailed test suite in Chapter 9.

Typical tolerance levels from AAPM TG53, IAEA TRS430 (examples):

- Square field CAX: 1%
- MLC penumbra: 3%
- Wedge outer beam: 5%
- Buildup-region: 30%
- 3D inhomogeneity CAX: 5%

For analysis of agreement between calculations and measurements, consider several regions.
Self-Consistent Measurements

Werner Heisenberg, 1958

WHAT WE OBSERVE IS NOT NATURE ITSELF

BUT NATURE EXPOSED TO OUR METHOD OF QUESTIONING.
- Measurements for commissioning & performance of TPS are the baseline for future routine QA.
- Configuration is benchmarked against measurements to characterize capacity to model treatment unit (geometry, dose).
- **Uncertainty** addresses confidence in the result of measurements; the dispersion of the values that could be observed.
- **Error** is deviation from the expected value.
- Both can be random or systematic.
- Only significant if they exceed a specified tolerance.
Dose Testing – Relative Distribution

Function to be tested: Regular field dosimetry

Criteria for assessing computed points (1st/2nd = Pass, 3rd = Marginal):

<table>
<thead>
<tr>
<th></th>
<th>1st</th>
<th>2nd</th>
<th>3rd</th>
</tr>
</thead>
<tbody>
<tr>
<td>Inside</td>
<td>± 1%</td>
<td>± 2%</td>
<td>± 3%</td>
</tr>
<tr>
<td>Outside</td>
<td>± 1%</td>
<td>± 2%</td>
<td>± 5%</td>
</tr>
<tr>
<td>Gradient</td>
<td>± 1mm</td>
<td>± 2mm</td>
<td>± 3mm</td>
</tr>
</tbody>
</table>

The functions, and relative dose factors (RDF) calculated on XXX are validated against commissioning measurements.

Operator: Louis St. Laurent, Arthur Meighen, Kim Campbell

Test environment: TPS v4.5.2/OmniPro

Use cases: N/A

Test specification: Adapted from Table 4-4 in AAPM TG-53 report


Result: Passed; see summary of results below

Procedure: Following beam model generation, generate beam model report.

Date: April 13, 2015

Beam Model Report: EV06
Energy: 18.0 MV

Summary: Points In All Geometries And Profiles

<table>
<thead>
<tr>
<th>POINTS</th>
<th>Total</th>
<th>Inside</th>
<th>Outside</th>
<th>Transit</th>
</tr>
</thead>
<tbody>
<tr>
<td>1st</td>
<td>25012 (82.6 %)</td>
<td>13807 (83.9 %)</td>
<td>8687 (76.7 %)</td>
<td>2518 (100.0 %)</td>
</tr>
<tr>
<td>2nd</td>
<td>29802 (98.4 %)</td>
<td>16318 (99.2 %)</td>
<td>10966 (96.9 %)</td>
<td>2518 (100.0 %)</td>
</tr>
<tr>
<td>3rd</td>
<td>30265 (99.9 %)</td>
<td>16428 (99.8 %)</td>
<td>11319 (100.0 %)</td>
<td>2518 (100.0 %)</td>
</tr>
</tbody>
</table>

Distance [cm]
Dose Testing – Dose Calibration

- Add Reference Calibration and Output Factors by performing MU comparisons on central axis for:
  - 6 to 8 jaw settings (X & Y), 5 or 6 depths
  - ~300 per beam model

### Table 9 – Summary of agreement between RadCalc and manual calculations for all beam models

<table>
<thead>
<tr>
<th></th>
<th>&lt;1%</th>
<th>&lt;2%</th>
<th>&lt;3%</th>
<th>&lt;4%</th>
<th>&lt;5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>ES07</td>
<td>75</td>
<td>98</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>6 MV</td>
<td>84</td>
<td>100</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>18 MV</td>
<td>92</td>
<td>98</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>EV06</td>
<td>82</td>
<td>99</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>6 MV</td>
<td>57</td>
<td>96</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>18 MV</td>
<td>78</td>
<td>99</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>6 MV FFF</td>
<td>78</td>
<td>99</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>SV01</td>
<td>55</td>
<td>97</td>
<td>98</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>NA09</td>
<td>64</td>
<td>99</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>6 MV</td>
<td>64</td>
<td>99</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>18 MV</td>
<td>67</td>
<td>99</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

### Table 10 – Summary of agreement between RadCalc and Pinnacle calculations for all beam models

<table>
<thead>
<tr>
<th></th>
<th>&lt;1%</th>
<th>&lt;2%</th>
<th>&lt;3%</th>
<th>&lt;4%</th>
<th>&lt;5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>ES07</td>
<td>63</td>
<td>90</td>
<td>99</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>6 MV</td>
<td>76</td>
<td>99</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>18 MV</td>
<td>62</td>
<td>93</td>
<td>99</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>EV06</td>
<td>61</td>
<td>86</td>
<td>99</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>6 MV</td>
<td>70</td>
<td>97</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>18 MV</td>
<td>73</td>
<td>92</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>6 MV FFF</td>
<td>73</td>
<td>92</td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>SV01</td>
<td>81</td>
<td>94</td>
<td>99</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>NA09</td>
<td>35</td>
<td>79</td>
<td>96</td>
<td>99</td>
<td>100</td>
</tr>
<tr>
<td>6 MV</td>
<td>81</td>
<td>94</td>
<td>99</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td>18 MV</td>
<td>81</td>
<td>94</td>
<td>99</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>
Dose Testing – Irregular Fields

Function to be tested: Irregular field dosimetry – EV06 6MV

Outcome: Verify TPS accuracy in predicting dose from MLC-shaped fields.

Operator: Louis St. Laurent, Arthur Meighen, Kim Campbell

Test environment: XXX TPS v4.5.2/Excel/RadCalc

Use cases: N/A

Test specification: Agreement within 1%

Test reference: AAPM TG-53 report

Result: Passed

Procedure: RDF measured for irregular fields shaped with MLC are compared with those calculated by XXX TPS. Results compiled in XXXTPSv4.5.2_commissioning_irregular_fields.xlsx

Date: April 13, 2015

<table>
<thead>
<tr>
<th>U-shape</th>
<th>Pnt 1</th>
<th>Pnt 2</th>
<th>Pnt 3</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>3cm depth</td>
<td>7cm depth</td>
<td>15 cm depth</td>
</tr>
<tr>
<td>EV06</td>
<td>-1.7</td>
<td>-1.1</td>
<td>-0.9</td>
</tr>
<tr>
<td>18 MV</td>
<td>0.6</td>
<td>-2.1</td>
<td>-1.5</td>
</tr>
<tr>
<td>ES07</td>
<td>0.6</td>
<td>0.2</td>
<td>0.5</td>
</tr>
<tr>
<td>18 MV</td>
<td>0.1</td>
<td>-0.5</td>
<td>0.1</td>
</tr>
<tr>
<td>SV01</td>
<td>-0.1</td>
<td>0.0</td>
<td>0.2</td>
</tr>
<tr>
<td>6 MV</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>FFF6 MV</td>
<td>0.4</td>
<td>-0.4</td>
<td>-1.3</td>
</tr>
<tr>
<td>NA09</td>
<td>0.4</td>
<td>0.3</td>
<td>0.3</td>
</tr>
<tr>
<td>18 MV</td>
<td>0.8</td>
<td>0.0</td>
<td>0.1</td>
</tr>
</tbody>
</table>

Table 12 - U-Shape irregular field percent agreement in monitor units calculated by RadCalc and Pinnacle for each geometry and beam model.
Detailed description of dosimetric tests are provided by:

A. Your Boss.
C. IAEA, "Commissioning and quality assurance of computerized planning systems for radiation treatment of cancer", TRS 430
D. All of the Above
Detailed description of tests are provided by:

A. Your Boss.
C. IAEA, "Commissioning and quality assurance of computerized planning systems for radiation treatment of cancer", TRS 430
D. All of the Above

Answer is C
## Routine Quality Control


<table>
<thead>
<tr>
<th>Frequency</th>
<th>Item</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily</td>
<td>Error logs&lt;br&gt;Hardware/software change logs</td>
</tr>
<tr>
<td>Weekly</td>
<td>Digitizer&lt;br&gt;Hardcopy output&lt;br&gt;Computer files&lt;br&gt;Review clinical treatment planning</td>
</tr>
<tr>
<td>Monthly</td>
<td>CT data input&lt;br&gt;Problem review&lt;br&gt;Review hardware, software and data files</td>
</tr>
<tr>
<td>Annually</td>
<td>Dose Calculations&lt;br&gt;Review digitizer, CT/MRI input, printers, etc.&lt;br&gt;Review BEV/DRR accuracy, CT geometry, density conversions, DVH calculations, data files and other critical data</td>
</tr>
<tr>
<td>Variable</td>
<td>Repeat commissioning due to machine changes or software upgrade</td>
</tr>
</tbody>
</table>

Hypothesis

- Variation in dosimetric performance within or between groups of patients planned with a common strategy will aid in improvement of dosimetric accuracy and precision.
Deming’s Sketch of the Shewhart Cycle for Learning and Improvement - 1985

**The Shewhart Cycle**

1. **Plan a change or a test aimed at improvement**
2. **Carry it out** (preferably on a small scale)
3. **Study the results. What did we learn?**
4. **Act**
   - Adopt the change, or abandon it.
   - Run through the cycle again, possibly under different environmental conditions.

*Dr. Walter Shewhart
Bell Labs, 1930*
A “New” Definition of Quality

- Variation is to be expected
- Common or special causes
- Tools to learn from variation

- Goal: On target with minimum variance
- This requires a different way of thinking of our processes.
- It is achieved only when a process displays a reasonable degree of statistical control

Deming’s System of Profound Knowledge

W. Edwards Deming 1900 - 1993
Understanding Variation: Tools

- Run Chart
- Shewhart Chart
- Frequency Plot
- Pareto Chart
- Scatterplot

**Distribution of Wait Times**

**Clinic Wait Times > 30 days**

**Relationship Between Long Waits and Capacity**
Statistical Process Control

- Statistical techniques to document, correct, and improve process performance.
- A control chart monitors variation over time;
  - Compare current process performance with historical performance - based on ~25 samples.
- SPC differs from setting specifications, although it informs process improvement and the ability to meet stated specifications.
- A process is described as “in control” when its performance is predictable in a statistical sense.
SPC Basic Procedure

- Choose an appropriate metric, time period for collection and plotting.
- Choose patient/plan cohort that is reasonably similar.
  - literature suggests need ~25 samples.
- Construct plot and analyze.
- Look for “out of control” events, investigate the cause.
  - Are there valid reason to exclude events?
- Are there systematic differences?
Process capability is a measure of the ability of a process to operate within its specification range. How many samples are needed to establish control limits to monitor IMRT using a control chart?

A. 5  
B. 10  
C. ~25  
D. >100  
E. 350
QUESTION

- Process capability is a measure of the ability of a process to operate within its specification range.
- How many samples are needed to establish control limits to monitor IMRT using a control chart?
  
  A. 5
  B. 10
  C. ~25
  D. >100
  E. 350

ANSWER: C


“Although we have demonstrated the requirement for about 25 measurements to characterize our head and neck IMRT process, there is a need to continue to monitor the process to ensure stability over a longer period of time.”
IMRT Process Monitoring

165 high-dose measurements - Head and neck IMRT
Pinnacle 7.6c (Sept – Dec, 2005)


-4 0 2 4
-2 0 2 50 75 100 125 150 175
Measurement

Per cent difference  

± 3σ  

mean
Process Change

- Old TPS Version
  - Beam modulated as an intensity matrix
  - Secondary conversion to MLC delivery
  - MLC modeled as an “ideal” collimator

- New TPS Version
  - Incorporates physical MLC model
    - Single-focus
    - Curved leaf face
    - transmission
    - “tongue and groove”
IMRT Verification Measurements

Head & Neck Cancers


Measurement discrepancy

6.2b – low dose
6.2b – high dose
7.6c – low dose
7.6c high dose

Aug 2005
Improved beam model

Improve beam model: verification

Retrospective

Prospective

Patient-Specific QC

Measured-Calculated Dose Agreement:

Prostate: 91.4% ± 4.1%
(25 patients, 175 beams)  (3%/2mm)

Dose Computed on Phantom
Patient-Specific QC

All VMAT - Pelvis Site Groups (GU, GI, GYN)
Arc Check - Absolute Dose – 3%/2mm
Patient-Specific QC

Measured-Calculated Dose Agreement:

Prostate: 91.4% ± 4.1%
(25 patients, 175 beams) (3%/2mm)

Spine SBRT: 77.1% ± 9.7%
(25 patients, 214 beams) (3%/2mm)

Why the Difference in Agreement?

Same Accelerator.
Same Measurement Device.
Beam Model?
Automated Beam Model Optimization

ABMOS

- Concept: Employ clinically relevant (IMRT-like) delivery in the beam modeling process.
- Challenge: Isolate key parameters; manipulate to enhance accuracy & precision of model across IMRT-type beams.
- Approach: Employ automated optimization methods.

IMRT Test Beam

- Open segments
- Jaw %T
- MLC
ABMOS Results

Date: 4/7/2015

MapCHECK QA of Dose Distribution

Hospital Name:

QA File Parameter
- Patient Name: ABMOS
- Patient ID: 999999
- Plan Date: 7/4/2015
- SSD: 913.5
- SDD: 1000.0
- Depth: 88.5
- Energy: 0
- Angle:

Relative Comparison
- Difference (%): ±2.0
- Distance (mm): ±1.0
- Threshold (%): ±5.0
- Meas Uncertainty: ±No

Summary (DTA Analysis)
- Total Points: 1079
- Passed: 933
- Failed: 146
- % Passed: 87.5

Dose Values in cGy
- MapCheck measurement March 2015: 223.34, 221.56, 220.10, 221.07
- RayStation calculation: 220.10, 221.07
- % Diff: 1.21, 0.31, 1.21, 0.75
- DTA(mm): 0.00, 0.00, NA
- Coords (x-y-cm):

Notes

### ABMOS vs. Previous Model

#### Measured-Calculated Dose Agreement

<table>
<thead>
<tr>
<th></th>
<th>Clinical</th>
<th>ABMOS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Prostate:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(25 patients, 175 beams)</td>
<td>91.4% ± 4.1%</td>
<td>98.2% ± 1.6%</td>
</tr>
<tr>
<td><strong>Spine SBRT:</strong></td>
<td>77.1% ± 9.7%</td>
<td>96.4% ± 2.8%</td>
</tr>
<tr>
<td>(25 patients, 214 beams)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Relative pass rate (±SD)</th>
<th>Initial model</th>
<th>Optimized model</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prostate cases (n=175 beams)</td>
<td>91.4% ± 4.1%</td>
<td>98.2% ± 1.6%</td>
</tr>
<tr>
<td>%ΔD/DTA: 3%/2 mm (2%/1 mm)</td>
<td>(73.1% ± 6.7%)</td>
<td>(89.4% ± 4.9%)</td>
</tr>
<tr>
<td>Paraspinal cases (n=214 beams)</td>
<td>77.1% ± 9.7%</td>
<td>96.4% ± 2.8%</td>
</tr>
<tr>
<td>%ΔD/DTA: 3%/2 mm (2%/1 mm)</td>
<td>(48.8% ± 10.0%)</td>
<td>(77.8% ± 7.2%)</td>
</tr>
</tbody>
</table>

Independent dose calculation

A representative point for each field and composite

±3%? Tolerance ±5%?

<table>
<thead>
<tr>
<th>Point Name</th>
<th>ICRU B</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coordinates (X, Y, Z)</td>
<td>(1.32, -46.45, 2.80)</td>
</tr>
<tr>
<td>Total Dose (cGy)</td>
<td>170.9</td>
</tr>
<tr>
<td>RTP Calculated Dose (cGy)</td>
<td>170.4</td>
</tr>
<tr>
<td>Percent Difference</td>
<td>0.3%</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Beam Description</th>
<th>Offsets X / Z</th>
<th>SSD / Depth</th>
<th>Point Dose (cGy)</th>
<th>RTP Dose (cGy)</th>
<th>% Diff</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ph2 RPO 200</td>
<td>-0.88 / 3.02</td>
<td>88.91 / 10.37</td>
<td>9.1</td>
<td>9.6</td>
<td>-4.6%</td>
</tr>
<tr>
<td>Ph2 RPO 240</td>
<td>-1.16 / 3.00</td>
<td>84.27 / 15.75</td>
<td>13.2</td>
<td>13.2</td>
<td>0.2%</td>
</tr>
<tr>
<td>Ph2 RAO 280</td>
<td>-0.90 / 2.98</td>
<td>92.71 / 8.07</td>
<td>22.7</td>
<td>22.0</td>
<td>3.4%</td>
</tr>
<tr>
<td>Ph2 RAO 320</td>
<td>-0.22 / 2.97</td>
<td>94.90 / 6.29</td>
<td>21.0</td>
<td>21.5</td>
<td>-2.7%</td>
</tr>
<tr>
<td>Ph2 ANT 0 X1</td>
<td>0.55 / 2.97</td>
<td>96.01 / 5.06</td>
<td>23.9</td>
<td>24.5</td>
<td>-2.6%</td>
</tr>
<tr>
<td>Ph2 LAO 40</td>
<td>1.08 / 2.99</td>
<td>96.37 / 4.10</td>
<td>17.2</td>
<td>17.4</td>
<td>-1.6%</td>
</tr>
<tr>
<td>Ph2 LAO 80</td>
<td>1.11 / 3.01</td>
<td>94.40 / 5.27</td>
<td>21.0</td>
<td>20.6</td>
<td>1.7%</td>
</tr>
<tr>
<td>Ph2 LPO 120</td>
<td>0.61 / 3.03</td>
<td>87.06 / 11.99</td>
<td>16.9</td>
<td>16.6</td>
<td>1.9%</td>
</tr>
<tr>
<td>Ph2 LPO 160</td>
<td>-0.18 / 3.03</td>
<td>85.78 / 13.12</td>
<td>26.0</td>
<td>25.0</td>
<td>4.1%</td>
</tr>
</tbody>
</table>
TPS vs 2nd Calculation

Pinnacle v9.2 - Elekta Agility - 6MV - July 2012 – Feb 2015

<table>
<thead>
<tr>
<th>Site</th>
<th>Plans</th>
<th>RTP:TPS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Head &amp; Neck</td>
<td>3871</td>
<td>1.001 +/- 0.043</td>
</tr>
<tr>
<td>Breast &amp; Chest</td>
<td>2156</td>
<td>0.9793 +/- 0.05</td>
</tr>
<tr>
<td>Abdomen/Pelvis</td>
<td>3376</td>
<td>1.002 +/- 0.023</td>
</tr>
<tr>
<td>CNS, Other</td>
<td>2575</td>
<td>0.997 +/- 0.024</td>
</tr>
</tbody>
</table>

- Largest variations occur with
  - tissue inhomogeneity, field size < 4cm,
  - increasing IMRT segments, depth > 24cm,
  - Rx points off-axis > 8cm
TPS vs 2nd Calculation, One Beam Model

~950 Prostate Cancer Treatments

Changes To RTP system
disease-based feedback

MODEL_VERSION
- 2005-12-22 14:48
- 2006-01-11 14:02
- 2007-09-25 14:40
- 2009-05-06 17:36

Drop Data
SUMMARY

- Showed examples of non-dosimetric tests
  - imaging, orientation and scales
- Use of TG53 criteria to assess commissioning
- Implementing routine quality assurance
  - Continuous Quality Improvement
  - Statistic Process Control
  - On Target, minimum variation
- Anticipate several new Reports from AAPM.
- If you “feel good” about patient-specific QC results, reduce your specification and seek improvement!