Acceptance Testing and Routine QA on an Elekta VersaHD

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Acceptance Testing and Routine QA on an Elekta VersaHD

- No conflicts of interest to disclose
Installation/Acceptance Timeline

May, 2013
Installation begins

June, 2013
Acceptance & Commissioning begins

July, 2013
Beam modeling begins

August, 2013
First patient treatment
Versa Overview

XVI kV imaging (CBCT & planar)
Versa Overview

iViewGT™
MV imaging (planar)
Versa Overview

- Treatment Modalities
  - 6 MV
  - 10 MV
  - 15 MV
  - 6 MV FFF
  - 10 MV FFF
  - 6 – 15 MeV

<table>
<thead>
<tr>
<th>Nominal energy</th>
<th>6MV</th>
<th>10MV</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maximum nominal dose rate (FFF)</td>
<td>1400</td>
<td>2200</td>
</tr>
</tbody>
</table>
Agility™ Head

- MLCs
  - Uppermost
  - No backup jaws
Agility™ Head

- Diaphragms
- Lowermost
Agility™ Head

- 80 MLC pairs
- 5mm width
- Up to 3.5 cm/s
Agility™ Head

With Dynamic Leaf Guide and MLC, effective leaf speed is 6.5 cm/s
Acceptance Procedure

- The scope of acceptance, commissioning, and routine tests of a machine is vast
- Only a portion of tests will be covered in this presentation as commonplace tests will be excluded.
Acceptance Procedure

- Relative Dosimetry Checks
  - PDDs
  - Profiles (crossline, inline).
Acceptance Procedure

• Relative Dosimetry Checks
  • Measurement equipment

Sun Nuclear 3DS

PTW 0.125 cm³ Semiflex Chambers

Sun Nuclear Edge Detector
Acceptance Procedure

• Relative Dosimetry Checks
  • Measurement equipment

  PTW 0.125 cm³ Semiflex Chambers

  • Ion chambers are dose rate dependent (as dose rate increases, ion collection efficiency decreases)
    • Dose per time
    • Dose per pulse
  • PTW 0.125 cm³ Semiflex has 99% collection efficiency if...
    • Dose per time ≤ 12 Gy/s
    • Dose per pulse ≤ 1 mGy
  • Versa maximum FFF dose rate is...
    • 0.4 Gy/s
    • 1 mGy /pulse

At reference conditions
Acceptance Procedure

• Relative Dosimetry Checks
  • Lang et al.\textsuperscript{1} studied collection efficiency vs. dose per pulse in FFF beams
    • PTW Semiflex (air-filled)
    • PTW microLion (liquid-filled).
Acceptance Procedure

- Relative Dosimetry Checks
  - Lang et al.\textsuperscript{1} studied collection efficiency vs. dose per pulse in FFF beams
Acceptance Procedure

- Relative Dosimetry Checks
  - Lang et al.\(^1\) conclusions
    - Don’t use liquid-filled ion chambers for FFF relative dosimetry
    - Air-filled ion chambers are suitable for FFF relative dosimetry
    - Be aware of your detector’s collection efficiency as a function of dose per time and dose per pulse.
Acceptance Procedure

- Relative Dosimetry Checks
  - Electrometer limitations
    - Electrometers can become overloaded
    - Be aware of the amp limit specification
    - Diodes have a higher sensitivity than ion chambers, resulting in a higher current through the electrometer.
Acceptance Procedure

- Relative Dosimetry Checks
  - Measurement Equipment
    - Sun Nuclear Edge Detector
    - Used for small fields (≤ 5 x 5 cm²)
    - The same n-type diode die in the Edge Detector has been shown to have small instantaneous dose rate dependence²
    - Energy dependence is insignificant for small field PDDs³
      - ± 1% agreement with RK chamber for 10 x 10 cm² PDD.
Acceptance Procedure

- Relative Dosimetry Checks
  - The reference detector can be placed inside of the head
  - Convenient because you never have to move the reference detector
  - Avoid perturbation in small fields
  - Remove head covers and 1 piece of lead.
Acceptance Procedure

- Relative Dosimetry Checks
  - Specification for penetrative quality (PDD)

![Graph showing PDD for 6MV and 6MV FFF beams with a marked 67.5% reading at 10 x 10 PDD.]
Acceptance Procedure

- Relative Dosimetry Checks
- FFF Beam Specification Profile

6MV FFF 30 x 30 Inline

78.8%
Acceptance Procedure

- Relative Dosimetry Checks
  - Small Field FFF Beam Profile

![Graph showing 6MV FFF 5 x 5 Inline with 4% Flatness]
Acceptance Procedure

- **iComCAT**
  - Application that enables an external system to transmit a treatment prescription to the treatment control system (TCS)
  - Create and send fields with customized segments
  - Useful for creating QA test fields.
    - Picket fence
    - Leaf speed
Acceptance Procedure

- iComCAT
  - Connects to the Elekta Treatment Network
Acceptance Procedure

- iComCAT

Field and control point definitions (send to linac)
Acceptance Procedure

- iComCAT

Control point definitions
Acceptance Procedure

- iComCAT

Record and verify (return from linac)
Acceptance Procedure

- 3D kV Imaging
  - Uniformity
  - Low contrast visibility
  - Spatial resolution
  - Transverse scale
  - Sagittal geometry
Acceptance Procedure

- 3D kV Imaging
  - CATPHAN 503 or 600 is required
  - Our institution uses CATPHAN 503, which has 3 modules
    - CTP404, CTP528, CTP486
Acceptance Procedure

- 3D kV Imaging Uniformity
  - Module is made of uniform material (approx. water)
  - Contains 5 uniform ROIs
  - Mean pixel value of each ROI is recorded using XVI software
  - Percentage difference of max and min is calculated
  - Tolerance is 2%
Acceptance Procedure

- 3D kV Low Contrast Visibility
  - Module made of several inserts of varying electron densities
  - Mean pixel value and standard deviation of Polystyrene and LDPE inserts are recorded using XVI software
  - Tolerance is ≤ 1.5%

![CTP404 Module Diagram]
Acceptance Procedure

- 3D kV Spatial Resolution
  - 1 through 21 lp/cm
  - Highest number lp/cm that can be seen is recorded
  - Tolerance is \( \geq 10 \) lp/cm
Acceptance Procedure

- 3D kV Transverse Scale
  - The distance between 2 sets of inserts is measured
  - Tolerance is ± 1mm
Acceptance Procedure

- 3D kV Sagittal Geometry
  - The distance between 2 alignment markers is recorded
  - Tolerance is ± 1mm
Acceptance Procedure

- 2D kV Imaging
  - Low contrast visibility
  - Spatial resolution

TOR 18FG Leeds Phantom
Acceptance Procedure

- 2D kV Imaging
  - Low contrast visibility
    - Count number of disks visible
    - A minimum of 12 disks must be seen
  - Spatial resolution
    - Count number of line pairs visible
    - Tolerance is $\geq 1.4 \text{ lp/mm}$
Acceptance Procedure

- kV and MV Registration Accuracy
  - Register CBCT to reference CT and apply shifts to ball-bearing phantom using vernier scale
  - Acquire MV images at 4 cardinal angles each at 0° and 180° collimator rotation
  - XVI software calculates registration accuracy
  - Tolerance is ≤ 1mm
Acceptance Procedure

- MV Image Quality
  - Contrast-detail phantom
  - Holes have varying thickness and diameter
  - Certain specified holes are required to be discernable in image
Acceptance Procedure

- Imaging QA Baselines
  - Following acceptance, imaging baselines should be established using the methods that will be used for routine QA
  - Our institution uses Mobius Medical Systems DoseLab with Sun Nuclear ImagePro phantoms
  - Baselines include spatial resolution, contrast, CBCT HU constancy, uniformity and noise.
Routine QA

- kV CBCT
  - CATPHAN 503 is used
Routine QA

- kV CBCT
  - DoseLab software automatically analyzes the CT data set and compares results to tolerances and baselines

Results (All tests pass):

Scaling discrepancy: 0.0 mm
Geometric distortion: 0.2 mm
Spatial resolution (50% MTF): 0.27 lp/mm
Overall uniformity: 98.1%
Minimum uniformity: 99.0% (ROI 22)
Contrast (ROIs 1 and 2): 9.9%
CNR (ROIs 1 and 2): 17.9
Max HU deviation: 191 HU (ROI 8)
Slice width: 1.18 mm (Off +0.18) mm
Routine QA

- MV Imaging
  - Sun Nuclear MV-QA phantom is used
  - 4 spatial resolution ROIs (0.1, 0.2, 0.5, 1.0 lp/mm)
  - 4 contrast ROIs
Routine QA

- MV Imaging
  - DoseLab software automatically analyzes the MV image and compares results to tolerances and baselines
Routine QA

- Imaging and treatment coordinate coincidence
  - Sun Nuclear WL-QA phantom is used

- $6 \times 6 \times 6 \text{ cm}^3$
- 8.0 mm metal sphere at the cube center
Routine QA

- Imaging and treatment coordinate coincidence
  - A CBCT is acquired and registered to the reference CT to align the sphere with the kV isocenter
Routine QA

- Imaging and treatment coordinate coincidence
  - Once the sphere is at kV isocenter, four 2 x 2 MV images are collected
  - MV images are measured at the cardinal angles with opposing field collimation rotated 180° apart.
Routine QA

- Imaging and treatment coordinate coincidence
- DoseLab software automatically analyzes the MV images and compares result to tolerance
Routine QA

- Leaf Position Accuracy
  - Picket fence field is used (created in iCom CAT)
  - 12 strips, 1 cm width, 22 cm height, 2 cm center to center, 21 MU per strip
  - Image collected on iViewGT MV panel.
Routine QA

- Leaf Position Accuracy
  - DoseLab software automatically analyzes the MV image and compares the results of each leaf to the tolerance
Routine QA

- Leaf Position Accuracy
  - DoseLab software automatically analyzes the MV image and compares the results of each leaf to the tolerance

- Recommendations for Elekta machines
  - Use a Gaussian fit instead of a Lorentzian fit
  - Ignore results near leaf junctions
Routine QA

- MLC Leaf Speed
  - Raw leaf positions vs time (seconds) are recorded in service graphing in service mode.
  - Raw leaf positions can be converted to cm if leaf travel distance is known.
  - At our institution, a single segment, low MU field (20MU) is delivered with all leaves traveling 25cm.
Routine QA

- MLC Leaf Speed

Data acquisition steps
- Begin Acquire
- Beam on (MLCs move 25cm)
- End Acquire
- Save file as .xml
- Import file into Excel and calculate cm/s for each leaf
Routine QA

- MLC Leaf Speed
  - Excel results

<table>
<thead>
<tr>
<th>Leaf</th>
<th>Baseline Speed (cm/s)</th>
<th>Meas. Speed (cm/s)</th>
<th>Abs. Diff. (cm/s)</th>
<th>TG-142 Tol. (cm/s)</th>
<th>Result</th>
</tr>
</thead>
<tbody>
<tr>
<td>Y1 1</td>
<td>3.8</td>
<td>3.8</td>
<td>0.0</td>
<td>0.5</td>
<td>Pass</td>
</tr>
<tr>
<td>Y1 2</td>
<td>3.8</td>
<td>3.8</td>
<td>0.0</td>
<td>0.5</td>
<td>Pass</td>
</tr>
<tr>
<td>Y1 3</td>
<td>3.8</td>
<td>3.8</td>
<td>0.0</td>
<td>0.5</td>
<td>Pass</td>
</tr>
<tr>
<td>Y1 4</td>
<td>3.8</td>
<td>3.8</td>
<td>0.0</td>
<td>0.5</td>
<td>Pass</td>
</tr>
<tr>
<td>Y1 5</td>
<td>3.8</td>
<td>3.8</td>
<td>0.0</td>
<td>0.5</td>
<td>Pass</td>
</tr>
<tr>
<td>Y1 6</td>
<td>3.8</td>
<td>3.8</td>
<td>0.0</td>
<td>0.5</td>
<td>Pass</td>
</tr>
<tr>
<td>Y1 7</td>
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<td>3.8</td>
<td>0.0</td>
<td>0.5</td>
<td>Pass</td>
</tr>
<tr>
<td>Y1 8</td>
<td>3.8</td>
<td>3.8</td>
<td>0.0</td>
<td>0.5</td>
<td>Pass</td>
</tr>
<tr>
<td>Y1 9</td>
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<td>Pass</td>
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<td>0.0</td>
<td>0.5</td>
<td>Pass</td>
</tr>
</tbody>
</table>
Routine QA

- Patient-specific QA
  - PTW OCTAVIUS II and OCTAVIUS 729 are used

- OCTAVIUS II
  - Polystyrene (~water equiv.)
  - 32 cm diameter

- OCTAVIUS 729
  - 729 vented ion chambers
Routine QA

- Patient-specific QA
  - OCTAVIUS 729 is suitable for dose rates up to 48 Gy/min or 0.8 Gy/s
  - Measuring range must be set to high for FFF in the data collection software
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Thank You!
References

