Acceptance Testing and Routine QA on an Elekta VersaHD



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No conflicts of interest to disclose

Installation/Acceptance Timeline



May, 2013 Installation begins

July, 2013 Beam modeling begins



June, 2013 Acceptance & Commissioning begins



August, 2013 First patient treatment

Versa Overview



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

| Nominal energy | 6MV | 10MV |
|---------------------------------|------|------|
| Maximum nominal dose rate (FFF) | 1400 | 2200 |









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

- 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.

Relative Dosimetry Checks

- PDDs
- Profiles (crossline, inline).

Relative Dosimetry Checks

• Measurement equipment

Sun Nuclear 3DS



PTW 0.125 cm³ Semiflex Chambers



Sun Nuclear Edge Detector



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 \leq 12 Gy/s
 - Dose per pulse $\leq 1 \text{ mGy}$
- Versa maximum FFF dose rate is...
 - 0.4 Gy/s

1 mGy /pulse

At reference conditions

Relative Dosimetry Checks

- Lang et al.¹ studied collection efficiency vs. dose per pulse in FFF beams
 - PTW Semiflex (air-filled)
 - PTW microLion (liquid-filled).

Relative Dosimetry Checks

• Lang et al.¹ studied collection efficiency vs. dose per pulse in FFF beams



- 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.

- 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.

Relative Dosimetry Checks

• Measurement Equipment

Sun Nuclear Edge Detector



- Used for small fields ($\leq 5 \times 5 \text{ cm}^2$)
- 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.

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.



Relative Dosimetry Checks

• Specification for penetrative quality (PDD)



Relative Dosimetry Checks

• FFF Beam Specification Profile

6MV FFF 30 x 30 Inline



| SPECIFICATION | | | | | | | | |
|--|--------------------------|--|--|--|--|--|--|--|
| Measurement point distance from CAX as a % of the half | Nominal relative dose | | | | | | | |
| field width | | | | | | | | |
| 20% | 94.6% | | | | | | | |
| 50% | 78.2% | | | | | | | |
| 80% | 62.6% | | | | | | | |

Relative Dosimetry Checks

• Small Field FFF Beam Profile



• 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

• iComCAT

Connects to the Elekta Treatment Network



• iComCAT

T AccTest5.efs - iCOM Customer Acceptance Test (Not For Clinical Use) File Edit View R & V Tools Help D 😅 📓 🔒 📾 💼 🎇 🏜 🎽 • K < H > . 68 8 Not For Clinical Use - See Help About iCOMCAT Vx Metrics Send Field Confirm Settings Unconfirm Settings Clear Field Message Frequency (Hz) 0.83 Max Message Interval (sec) 1.40 Fx Vx ID Name Dose Administration Entry Target ID Name Patient ACC05.EFS Prescribed Patient ACC05.EFS Treatment Treatment Accumulated Beam Beam #5 Beam Beam #5 Beam Complexity Technique SimpleArc Accumulated Beam Leaf Width 1 Machine 6944 Session Finish Field 6844 Leaf Width Machine For Machine 6844 Beam MU 100 Delivered Control Points Reasons Pres. Set Rin CP 1 CP 2 CP **B&V** Inhibi Beam MU 100.0 100.0 100.0 Cum. Beam MU % 0 70 100 Segment MU1 30.0 30.0 Inhibits. Dose Rate Segment MU 2 32.0 30.0 Energy 6 MV 6 MV Step MU 30.0 30.0 Fluence Mode Wedged MU 30.0 30.0 XRAY XRAY **Radiation Type** Beam Timer 0.6 Wedge Position OUT IN ControlPoints Accessory 2 **DeliverySegments** Applicator Dose Rate Diaphragm Angle Interrupts 6 MV 6 MV Energy **Diaphragm Direction** Fluence Mode Diaphragm X1 10 **Radiation Type** X-Rays X-Rays Diaphragm X2 10 Terminates D1 Sg end Segment ID Diaphragm V1 10 Wedge Position IN IN Diaphragm Y2 10 Accessory 0 Fitment Contra Annali Geometrics MLC Ext. Channels Geometrics T MLC Ext. Channels Ready Fx: Connected OK Vx: Connected Seq No: 423 Field Terminated

Field and control point definitions (send to linac)

• iComCAT

| | -10 IG | Fr 1 | | • K < F | * > > 7 | | | | | | . 6 | 2 | | |
|---------------------------|----------|----------|---------------|-------------|----------------|----------------|--------|------------|------------|-----|------------------------------|------------------------|---------------------|-----|
| ot For Clinical Use - See | Help Ab | out iCOM | CAT | | Vx Metrics | | | | | | | | | |
| end Field | Settings | Uncon | firm Settings | Clear Field | Message Frequ | ency (Hz) 0.83 | Max Me | ssage Inte | rval (sec) | .40 | | | | |
| Fx | ID | | N | - | Vx | | | | | | | | | - |
| Patient ACC05.EF | FS | | ne. | | | ID Name | | | | | Dose Administration Entry Ta | | | |
| Treatment | | — ii | | | Patient | ACC05.EFS | | | | _ | Prescribed | | | |
| Beam 5 | | - 1 | Beam #5 | | Treatment | | | | | | Accumulate | d | | |
| Complexity | | | | | Beam | Cimeladua | | Beam #5 | | _ | Beam | | | |
| | | | | | Technique | SimpleArc | | Leafly | Cal 1 | | Accumulate | dBeam | | |
| Machine 6844 | Finis | h Field | Leaf | Width | Machine | 0044 | | Learv | vidin i | | Session | | | |
| Beam MU 100 | Delivere | d | Control | Points 3 | r or machine | 0044 | | | | | Dessent | | | |
| | CP 1 | CP 2 | CP 3 | × | | | Pres. | Set | Run | • | neasons | | | |
| Cum. Beam MU % | 0 | 70 | 100 | | Beam MU | | 100.0 | 100.0 | 100.0 | 1 | H&V Inhibit | | | |
| Dose Rate | | | | | Segment M | 1U 1 | | 30.0 | 30.0 | | Inhibits | Settings Not Confirmed | | med |
| Energy | 6 MV | 6 MV | | | Segment M | 1U 2 | | 32.0 | 30.0 | | | megnyri | integry (for freedy | |
| Fluence Mode | | | | | Step MU | | | 30.0 | 30.0 | | | | | |
| Radiation Type | XRAY | XRAY | | | Wedged M | U | 1 | 30.0 | 30.0 | | | | | |
| Wedge Position | OUT | IN | | | Beam Time | a. | | | 0.6 | | | | | |
| Accessory | 0 | | | | ControlPoi | nts | | | 3 | | | | | |
| Applicator | | | | | DeliverySeg | gments | | | 2 | | | | | |
| Diaphragm Angle | 0 | | | | Dose Rate | | - | | 0 | | Internente | | | |
| Diaphragm Direction | | | | | Energy | | _ | 6 MV | 6 MV | | in Kentupus | | | |
| Diaphragm X1 | 10 | | | | Fluence Mo | ode | | | | | | | | |
| Diaphragm X2 | 10 | | | | Radiation T | ype | | X-Rays | X-Rays | | Terminator | D1 Sa e | nd | |
| Diaphragm Y1 | 10 | | | | Segment ID |) | 2 | 2 | 2 | | i erminares | or sy e | | |
| Diaphragm Y2 | 10 | | | | Wedge Pos | ation | | IN | IN | | | | | |
| Fitment | | - | | | Accessory | | | 0 | 0 | + | | | | |
| Conter Anala | 0 | | 0 | | Countries to a | Entr | | F. 4. Ch | and an | | | | | |

Control point definitions

• iComCAT

| A For Christiller Con | I.L. AL | | CAT | | | | | | | _ | | | | | | | | |
|---------------------------|----------|---------|----------------|-----------|-----------------|----------------|--------|------------|------------|------|---------------------|------------|--------|----------------|------|--------|--------|-------|
| tot For Linical Use - See | Help Ab | | | | Vx Metrics | 10000 | | 12 | | | | | | | | | | |
| Send Field | ettings | Uncont | irm Settings C | ear Field | Message Frequ | ency (Hz) 0.83 | Max Me | ssage Inte | rval (sec) | 1.40 | | | | | | | | |
| Fx | ID | | Name | | Vx | ID | | | Name | | Dose Administration | n Entry | Target | | | | | |
| Patient ACC05.EF | S | | | | Patient | ACC05.EFS | | | | | Prescribed | | | | | | | |
| Treatment | | | | | Treatment | | | | | - | Accumulated | | | | | | | |
| Beam 5 | | 1 | Beam #5 | | Beam | | | Beam #5 | | | Beam | | | | | | | |
| Complexity | | | | | Technique | SimpleArc | | | | | Accumulated Rean | | | | | | | |
| | | | | | Machine | 6844 | | Leaf | vidth 1 | | Cassion | | | | | | | |
| Machine 6844 | Finis | h Field | Leaf Width | | For Machine | 6844 | | | | | Session | | | | | | | |
| Beam MU 100 | Delivere | d | Control Points | 3 | T OF THOSE BILL | | | | | | Reasons | | | | | | | |
| | CP 1 | CP 2 | CP 3 | | | | Pres | Set | Run | | Devilate | | | | | | | |
| Cum. Beam MU % | 0 | 70 | 100 | | Beam MU | | 100.0 | 100.0 | 100.0 | | Piev Innibit | | | | | | | |
| Dose Rate | | | | | Segment N | IU 1 | | 30.0 | 30.0 | | Inhibits Settin | gs Not Con | firmed | | | | | |
| Energy | 6 MV | 6 MV | | | Segment N | IU 2 | | 32.0 | 30.0 | | integr | (y nut nea | -97 | | | | | |
| Fluence Mode | | | | | Step MU | | | 30.0 | 30.0 | | | | | | | | | |
| Radiation Type | XRAY | XRAY | | | Wedged M | U | | 30.0 | 30.0 | | | | | | | | | |
| Wedge Position | OUT | IN | | | Beam Time | r | | | 0.6 | | | | | | | | | |
| Accessory | 0 | | | | ControlPoi | nts | | | 3 | | | | | D | | rd ar | dva | cif. |
| Applicator | | | | | DeliverySeg | ments | | | 2 | | | | | | eco | u ai | iu ve | і п у |
| Diaphragm Angle | 0 | - | | | Dose Rate | | | | 0 | | | | | , | | c | | |
| Diaphragm Direction | | | | | Energy | | | 6 MV | 6 MV | | Interrupts | | | (\mathbf{r}) | etur | 'n tro | om lir | nac |
| Diaphragm X1 | 10 | | | | Fluence Me | de | | | | | | | | | | | | |
| Diaphragm X2 | 10 | | | | Radiation T | ype | | X-Rays | X-Rays | | | | | | | | | |
| Diaphragm Y1 | 10 | | | | Segment II |) | 2 | 2 | 2 | | Terminates D1 Sg | , end | | | | | | |
| Diaphragm Y2 | 10 | | | | Wedge Pos | ition | | IN | IN | | | | | | | | | |
| Fitment | | | | | Accessory | | | 0 | 0 | | | | | | | | | |
| | 0 | 00 | 0 | ÷ | Annliester | | | | | * | | | | | | | | |

• 3D kV Imaging

- Uniformity
- Low contrast visibility
- Spatial resolution
- Transverse scale
- Sagittal geometry

• 3D kV Imaging

- CATPHAN 503 or 600 is required
- Our institution uses CATPHAN 503, which has 3 modules
 - CTP404, CTP528, CTP486

CATPHAN 503



• 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%

CTP₄86 Module



• 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

$$\frac{(CT_{polystyrene} - CT_{LDPE})/10}{\left\{\frac{(Mean_{polystyrene} - Mean_{LDPE})}{(SD_{polystyrene} + SD_{LDPE})/2}\right\}}$$

CTP404 Module



• Tolerance is $\leq 1.5\%$

• 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



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





• 3D kV Sagittal Geometry

- The distance between 2 alignment markers is recorded
- Tolerance is ± 1mm



• 2D kV Imaging

- Low contrast visibility
- Spatial resolution

TOR 18FG Leeds Phantom



• 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 lp/mm

TOR 18FG Leeds Phantom



• 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 o° and 180° collimator rotation
- XVI software calculates registration accuracy
- Tolerance is ≤ 1 mm

Ball-bearing phantom



• MV Image Quality

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

Las Vegas phantom



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.

• kV CBCT

• CATPHAN 503 is used



• 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



• 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

• MV Imaging

• DoseLab software automatically analyzes the MV image and compares results to tolerances and baselines



Results (All tests pass):

Scaling discrepancy: 0.0 mm Spatial resolution (70% MTF): 0.25 lp/mm Minimum uniformity: 99.6% (ROI 1) Contrast (ROIs 3 and 5): 17.5% CNR (ROIs 3 and 5): 61.8

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



- 6 x 6 x 6 cm³
- 8.0 mm metal sphere at the cube center

• Imaging and treatment coordinate coincidence

• A CBCT is acquired and registered to the reference CT to align the sphere with the kV isocenter



- 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.

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



- 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.

Leaf Position Accuracy

• DoseLab software automatically analyzes the MV image and compares the results of each leaf to the tolerance



Leaves that failed: None Maximum difference: 0.28 mm Standard deviation: 0.10 mm

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

- 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.

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

- MLC Leaf Speed
 - Excel results

| Leaf | Baseline Speed (cm/s) | Meas. Speed (cm/s) | Abs. Diff. (cm/s) | TG-142 Tol. (cm/s) | Result |
|-------|-----------------------------|--------------------------|----------------------|--------------------------|--------|
| Y11 | 3.8 | 3.8 | 0.0 | 0.5 | Pass |
| Y12 | 3.8 | 3.8 | 0.0 | 0.5 | Pass |
| Y1 3 | 3.8 | 3.8 | 0.0 | 0.5 | Pass |
| Y14 | 3.8 | 3.8 | 0.0 | 0.5 | Pass |
| Y1 5 | 3.8 | 3.8 | 0.0 | 0.5 | Pass |
| Y16 | 3.8 | 3.8 | 0.0 | 0.5 | Pass |
| Y17 | 3.8 | 3.8 | 0.0 | 0.5 | Pass |
| Y1 8 | 3.8 | 3.8 | 0.0 | 0.5 | Pass |
| Y1 9 | 3.8 | 3.8 | 0.0 | 0.5 | Pass |
| Y1 10 | 3.8 | 3.8 | 0.0 | 0.5 | Pass |

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

- 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



Acceptance Testing and Routine QA on an Elekta VersaHD



Thank You!

References

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