Commissioning of volumetric modulated arc therapy (VMAT)

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What is VMAT?

**Volumetric Modulated Arc Therapy**
Arc therapy technique

Arc Therapy (Cobalt, 1940’s – 1950’s)
Conformal Arc Therapy (Dynamic)
  (Takahashi, 1965)
IMAT (it is necessary to modulate the arc)
  (Brahme 1982)
Optimization and variation in gantry speed, collimator angle and dose rate
  (Chin 1983)
VMAT (Developed by Yu 1995)
Treatments in William Beamount (2006)
Modelation verification

When we receive the modelated beams, it is necessary to check the reference fields
Monte Carlo (MONACO) model verification

Resolution: 1 mm (field size < 16 x 16 cm x cm)
2 mm (field size ≥ 16 x 16 cm x cm)

Variance: 1% (MONACO, Monte Carlo)

Gamma Index: 2%
6 MV, Monte Carlo
Field Size: 15 x 15 mm
Depth: 1.5 cm
Crossplane
6 MV, Monte Carlo
Field Size: 15 x 15 mm
Depth: 1.5 cm
Inplane
6 MV, Monte Carlo
Field Size: 15 x 15 mm
Depth: 10 cm
Crossplane
6 MV, Monte Carlo
Field Size: 25 x 25 mm
Depth: 1.5 cm
Crossplane
6 MV, Monte Carlo
Field Size: 25 x 25 mm
Depth: 1.5 cm
Inplane
6 MV, Monte Carlo
Field Size: 25 x 25 mm
Depth: 10 cm
Crossplane
6 MV, Monte Carlo
Field Size: 40 x 40 mm
Depth: 1.5 cm
Crossplane

Dose diff (%)

Gamma Index
6 MV, Monte Carlo
Field Size: 40 x 40 mm
Depth: 1.5 cm
Inplane
6 MV, Monte Carlo
Field Size: 40 x 40 mm
Depth: 20 cm
Crossplane
6 MV, Monte Carlo
Field Size: 40 x 40 mm
Depth: 20 cm
Inplane
6 MV, Monte Carlo
Field Size: 100 x 100 mm
Depth: 10 cm
Crossplane
6 MV, Monte Carlo
Field Size: 100 x 100 mm
Depth: 10 cm
Inplane
6 MV, Monte Carlo
Field Size: 20 x 20 mm
6 MV, Monte Carlo
Field Size: 40 x 40 mm
Is not easy to prepare a set of plans and modify any treatment parameters (gantry speed, dose rate, leaf speed, ...) keeping constant the others...

... so we can check the different parameters one by one or simultaneously
What can we “move”? (degrees of freedom)

In a Radiotherapy treatment with LINAC’s, the geometric parameters are:

- Gantry angle and speed
- Collimator angle
- Primary collimator position and speed
- Leaves position and speed
- Dose Rate
- Energy
- Pedestal angle
- Table couch position
First suggested tests for VMAT QA:
Ling, Bedford (2008)

Next: Létourneau, Metha, Mohan (2009),
Van E, Huyskens (2011)


Spanish Protocol (WIP)

Test 1: Leaf position accuracy

**Objective**: Verify the leaf accuracy positioning during the gantry rotation (arc)

**Test type**: Acceptance, constancy

**Equipment**: Portal view system, film (⊥)

**Human resources**: Physicist and/or Technician

**Procedure**: Design and irradiate a particular treatment plan
Test 1: Leaf position accuracy (cont.)

Analysis: Visual, pixel by pixel (MP38, 2011, 1425)

Tolerance: 0.5 mm (ESTRO Guidelines 2008)

Required time: Less than 1 hour

Periodicity: Acceptance and weekly
Test 2: Dose rate homogeneity during one arc

Objective: Verify the Linac stability and homogeneity during one arc with an open field

Test type: Acceptance, constancy

Equipment: Ionization chamber (located at isocenter) and electrometer
Test 2: Dose rate homogeneity during one arc (cont.)

Human resources: Physicist and/or Technician

Procedure: Gantry at 0°, 90°, 180°, 270°. Dose variation less than 1%
Two interrupted (twice) 90° arcs / partial arcs with minimum amplitude = 5°
Test 2: Dose rate homogeneity during one arc (cont.)

Results analysis: For each energy and arc fraction, compare the arc fraction and total arc.

Tolerance: Less than 1% for static and less or equal than 2% for dynamic.

Required time: 1 hour per energy.

Periodicity: Acceptance, Monthly (?), Yearly (?)
Test 3: Dose rate variation and gantry speed (V)

**Objective:** Verify the dose rate variation and gantry speed

**Test type:** Acceptance, constancy

**Equipment:** Portal view system, film (⊥)

**Human resources:** Physicist and/or Technician

**Procedure:** Obtain the image and normalize with respect to open field (avoid detector problems)
<table>
<thead>
<tr>
<th>Band number</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
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<tr>
<td>MU</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
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<td>3</td>
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<tr>
<td>Dose rate</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>6</td>
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<td>(UM/min)</td>
<td>0</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>0</td>
<td>0</td>
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<tr>
<td>Gantry speed</td>
<td>5x10</td>
<td>pixel area</td>
<td>1.8 cm</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>(º/seg)</td>
<td>4.8</td>
<td>4.8</td>
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<td>4.4</td>
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</tbody>
</table>

1 - 82.5º
2 - 41.2º
3 - 27.5º
4 - 20.7º
5 - 16.5º
6 - 14.6º
7 - 13.2º
Total: 296.2º
Test 3: Dose rate and gantry speed (V) (cont.)

**Results analysis:** Obtain the mean pixel value in a 5 x 10 pixels area. Normalize with respect the open field. Obtain the mean value of mean values of all bands.

**Tolerance:** Less or equal than 2% of difference in all areas normalized pixels values with respect the mean normalized value.

**Required time:** 1 hour per energy

**Periodicity:** Acceptance, Monthly (?),
Spanish Protocol ( WIP )

Test 4: Leaf speed ( V )

**Objective**: Verify the leaf accuracy positioning and speed uniformity during the gantry rotation. One treatment plan with different speed zones for each leave but, in combination with dose rate and gantry speed, obtain a set of homogeneous dose zones.

**Test type**: Acceptance, constancy

**Equipment**: Portal view, film (⊥)
<table>
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<tr>
<th align="center">$V_{\text{leaf}}$</th>
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<table>
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Spanish Protocol (WIP)

Test 4: Leaf speed (V) (cont)

Human resources: Physicist and/or Technician

Procedure: Obtain the image and normalize with respect to an open field (avoid problems with detectors)

Results analysis: Measure the variation of the mean normalized pixels area values with respect to the median value of all areas
Spanish Protocol (WIP)

Test 4: Leaf speed (V) (cont)

Tolerance: Less or equal than 2%
Required time: 1 hour
Periodicity: Acceptance, Monthly
Test 5: Collimator, gantry and dose rate simultaneously (E)

Objective: Verify the correct simultaneously operation of all dynamic VMAT treatment parameters (coll., gantry and dose rate)

Test type: Acceptance, constancy,

Equipment: Portal view system, film (⊥)

Human resources: Physicist and / or Technician
310° (50°) 335° (25°) 0°

1 leaf

5 leaves

5 leaves

5 leaves

1 leaf
Spanish Protocol (WIP)

Test 5: Collimator, gantry and dose rate simultaneously (E) (cont.)

Procedure: 100° partial arc from 310° to 50° (0° centered). Each dose rate must be verified separately. UM = Dose rate. Normalize with respect to open field for avoiding problems with detectors.

Result analysis: Measure each width step and each % step.
Spanish Protocol (WIP)

**Test 5: Collimator, gantry and dose rate simultaneously (E) (cont.)**

**Tolerance:** Dose homogeneity (inside each step) in the ± 3 % range. Width step: 5 cm (50 % of profile). Maximum gantry speed: 6º /seg. Dose per angle in the range 0.1 and 100 UM/º. Leaf speed less or equal than 2 cm/seg

**Time:** ½ hour

**Periodicity:** Acceptance and after collimator replacement
There are two possible ways to standardize the VMAT QA:

- Class solution
- Individual solution
Class solution

The “class solution“ try to find a beam configuration valid for all the treatments (or, at least, one configuration per pathology) and, in this way, avoid to test each individual treatment.
Individual solution

The "individual solution" proposes the individual treatment verification (this solution try to avoid the individual tests because each treatment uses to have a particular parameters combination and can not be replaced for an individual test set)
What do we do?

Each clinic, or hospital, must have a QA program based in:

- Process knowledge
- IMRT experience (VMAT more complex)
- QA device available
- Linac time
- Number of patients
- ....
QA equipment
2D arrays

- Mapcheck (Sunnuclear)
- MatriXX (IBA)
- seven29 (PTW)
Delta4 (Scandidos)
System is synchronized with the Linac pulses (no noise between pulses!) using terminal ST.
Arc Check
(Sun Nuclear)
XII Medical Physics Journey
(Brazilian Medical Physics Association)

June 21th-23rd 2012 - Curitiba

¡Thank you!

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