Automating AAPM TG-142 Quality Assurance Tests Using XML and Python Scripts

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INTRODUCTION

Annual linac output measurements, including monitor unit linearity and photon output factor constancy, are generally performed and recorded manually over many evenings. These manual tests lead to data entry errors, restarts, and lengthier time expenditures that are unnecessary. Quality assurance (QA) automation efforts are underway, but largely focus on mechanical and imaging checks that do not require accurate output measurements.[(1)] This work seeks to automate as much of linac QA as is practical with a simple ion chamber in solid water setup. To push this to its limit, TrueBeam Developer Mode[(2)] is utilized with adept scripts to enable autodetection and storage by a digital electrometer. Then, data is extracted directly from this storage.

AIM

To automate four separate tests required by TG-142[(3)] for output QA by compressing them into one innovative, coded method that automatically records and inputs results into a readable and reproducible format.

METHOD

A PTW 23333 ion chamber (PTW, Munich, Germany) was placed in 40x40 cm^2 solid water and connected to a PTW UNIDOS^{webline} electrometer to test our TrueBeam (Varian Medical Systems, Palo Alto, CA). XML scripts were created for TrueBeam Developer Mode using the SAGE application in Microsoft Excel.[(4)] The autodetection and storage features of the UNIDOS^{webline} record and store up to 100 measurements, delayed only by electrometer reset. The minimum time required between electrometer readings was measured, then scripted as a collimator rotation at default rotation speed. Scripts incorporated a chamber warmup and tests of monitor unit linearity, dose rate linearity, photon output factor constancy, enhanced dynamic wedge (EDW) factor constancy, and output constancy checks at the beginning and end of the script for a single energy without interruption. An in-house application was developed to translate raw binary output from the electrometer into a readable spreadsheet. A mock QA was performed for 4 photon and 3 electron energies and timed with a stopwatch.

RESULTS

Full scripts were created for 6X, 10X, and 15X, while energies 10FFF, 6E, 9E, and 12E did not require EDW factors. Scripts cannot automate electron output factor constancy checks since electron cones must be manually switched. All scripts were optimized to minimize duration, with 88 measurements for full scripts. A sample is shown in Figure 2 made from inputs shown in Figure 1. Early attempts at these scripts were written to minimize collimator rotation time, but it was found that measurements were lost due to the electrometer resetting too early. A minimum of 2 seconds is required to ensure no measurements are lost, which translates to a collimator rotation of 15º for photons and 6º for electrons. All results found from these scripts and mock QA were within annual TG-142 tolerances.

The mock QA, with automated scripts and recordings, took 2.49 hours, as indicated in Table 1. This included cone insertion between 15X and 6E, and depth adjustments to d_{max} between 6E/9E and 9E/12E. Measurements were collected and recorded automatically, removing the need for manual beam control or data entry. In fact, compared to the manual annual QA process, the mock QA was two times faster and free of data entry errors. Table 2, with a sample timed manual photon recording, took 0.69 hours alone. Based on departmental clinical experience, output QA takes at least 2 hours per evening over 3 to 4 evenings, with manual mistakes and setup confusion due to unclear documentation. This is particularly troublesome when reviewing previous year's results. A 7 script mock QA not only required much less time, but had no input mistakes.

Comment for XML: This is the XML for the free format example : *Just enter a comment to put in your XML here*
Energy: 6x : *Enter here the beam energy*
Y Jaws Slit length: ‹Perfect.xml : *The length of the slit formed by Y jaws. Here select length*
Dose Rate: 600 MU/min : *Irradiation happens at this dose rate. Select dose rate here*

MU	Gantry Angle	Table Vertical	Table Lateral	Table Long	Table Rotation	Coll Rotation	Y1	Y2	X1	X2	MLC Leaf B1	MLC Leaf B2	MLC Leaf B3	MLC Leaf B4
0.000 MU	180.000 °					180.00°	5.000 cm	5.000 cm	5.000 cm	5.000 cm	10.000	10.000	10.000	10.000
500.000 MU	180.000 °					180.00°	5.000 cm	5.000 cm	5.000 cm	5.000 cm	10.000	10.000	10.000	10.000
500.000 MU	180.000 °					195.00°	5.000 cm	5.000 cm	5.000 cm	5.000 cm	10.000	10.000	10.000	10.000
500.000 MU	180.000 °					180.00°	5.000 cm	5.000 cm	5.000 cm	5.000 cm	10.000	10.000	10.000	10.000
600.000 MU	180.000 °					180.00°	5.000 cm	5.000 cm	5.000 cm	5.000 cm	10.000	10.000	10.000	10.000
600.000 MU	180.000 °					195.00°	5.000 cm	5.000 cm	5.000 cm	5.000 cm	10.000	10.000	10.000	10.000
600.000 MU	180.000 °					180.00°	5.000 cm	5.000 cm	5.000 cm	5.000 cm	10.000	10.000	10.000	10.000
700.000 MU	180.000 °					180.00°	5.000 cm	5.000 cm	5.000 cm	5.000 cm	10.000	10.000	10.000	10.000
700.000 MU	180.000 °					195.00°	5.000 cm	5.000 cm	5.000 cm	5.000 cm	10.000	10.000	10.000	10.000
700.000 MU	180.000 °					180.00°	5.000 cm	5.000 cm	5.000 cm	5.000 cm	10.000	10.000	10.000	10.000
800.000 MU	180.000 °					180.00°	5.000 cm	5.000 cm	5.000 cm	5.000 cm	10.000	10.000	10.000	10.000
800.000 MU	180.000 °					195.00°	5.000 cm	5.000 cm	5.000 cm	5.000 cm	10.000	10.000	10.000	10.000
800.000 MU	180.000 °					180.00°	5.000 cm	5.000 cm	5.000 cm	5.000 cm	10.000	10.000	10.000	10.000
801.000 MU	180.000 °					180.00°	5.000 cm	5.000 cm	5.000 cm	5.000 cm	10.000	10.000	10.000	10.000
801.000 MU	180.000 °					195.00°	5.000 cm	5.000 cm	5.000 cm	5.000 cm	10.000	10.000	10.000	10.000
801.000 MU	180.000 °					180.00°	5.000 cm	5.000 cm	5.000 cm	5.000 cm	10.000	10.000	10.000	10.000
802.000 MU	180.000 °					180.00°	5.000 cm	5.000 cm	5.000 cm	5.000 cm	10.000	10.000	10.000	10.000
802.000 MU	180.000 °					195.00°	5.000 cm	5.000 cm	5.000 cm	5.000 cm	10.000	10.000	10.000	10.000
802.000 MU	180.000 °					180.00°	5.000 cm	5.000 cm	5.000 cm	5.000 cm	10.000	10.000	10.000	10.000
804.000 MU	180.000 °					180.00°	5.000 cm	5.000 cm	5.000 cm	5.000 cm	10.000	10.000	10.000	10.000
804.000 MU	180.000 °					195.00°	5.000 cm	5.000 cm	5.000 cm	5.000 cm	10.000	10.000	10.000	10.000
804.000 MU	180.000 °					180.00°	5.000 cm	5.000 cm	5.000 cm	5.000 cm	10.000	10.000	10.000	10.000
806.000 MU	180.000 °					180.00°	5.000 cm	5.000 cm	5.000 cm	5.000 cm	10.000	10.000	10.000	10.000
806.000 MU	180.000 °					195.00°	5.000 cm	5.000 cm	5.000 cm	5.000 cm	10.000	10.000	10.000	10.000

Figure 1: SAGE inputs used for 6X energy. Monitor units, collimator rotations, jaws, and MLC leaf positions are primarily what is adjusted between control points. The SAGE application generates a usable XML script based on these inputs.

```xml
<ControlPoints>
  <Cp> <!--0-->
    <SubBeam>
      <Seq>0</Seq>
      <Name></Name>
    </SubBeam>
    <!-- MV Beam type (x,FFF, SRS, HDTSE,e) and energy in MV... -->
    <Energy>6x</Energy>
    <Mu>0</Mu>
    <DRate>600</DRate>
    <GantryRtn>180.000000</GantryRtn>
    <CollRtn>180.000000</CollRtn>
    <Y1>5.000000</Y1>
    <Y2>5.000000</Y2>
    <X1>5.000000</X1>
    <X2>5.000000</X2>
    <Mlc>
      <ID>1</ID>
      <B>10.000000 10.000000 10.000000 10.000000 10.000000 10.000000
      <A>10.000000 10.000000 10.000000 10.000000 10.000000 10.000000
    </Mlc>
  </Cp>
```

Figure 2: Part of the generated XML script corresponding to the 6X photon energy Excel file in Figure 1. This figure only shows the first control point to highlight TrueBeam Developer Mode's ability to alter energy type, monitor units being fired, dose rate, gantry rotation, collimator rotation, collimator jaw size, and MLC leaf position. As done, one can create scripts for each energy that fulfil all QA requirements so that each TG-142 test does not have to be run separately, and one does not have to manually fire monitor units, shift the collimator, or any other part of the process.

Energy	Mock QA Duration (min)
6x	32.55
10x	31.90
15x	33.29
10FFF	9.04
6E	14.38
9E	13.96
12E	14.17
Total Time	149.3 min = 2.49 hours

Table 1: Cumulative durations for each energy during a mock QA using the 7 consecutive automation scripts. Recorded time is the length of time to run the script, record all data, and move on to next script.

TG-142 Test One Sample Photon Energy	Manual QA Time (min)
Monitor Unit (MU) Linearity	12.90
Photon Output Factors	12.16
Dose Rate Linearity	7.87
Enhanced Dynamic Wedge (EDW) Factor	8.46
Total Time	41.4 min. = 0.69 hours

Table 2: A sample manual QA timed for one photon energy for reference and comparison.

CONCLUSIONS

This method removes much human error while providing at least a two-fold decrease in physics resources required for annual output QA of a TrueBeam with Developer Mode. It is practical and beneficial to automate the QA process with automatic electrometer detection. Furthermore, this technique indicates a means to easily complete this task within one 3 hour work session.

Future work will seek the ideal electrometer for this method. Further scripts will be developed to fulfill other tests as desired by clinics that are not ours, while reducing wasteful time in conjunction with maintaining accurate results.

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