Proceedings Article

□ Dynamic comprehensive tomotherapy daily quality assurance

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SUMMARY: *A phantom and software specifically designed to be used for daily quality assurance measurements of the radiation beam characteristics of the tomotherapy Hi-Art machine. Both the phantom and the accompanied software provide rotational output and energy consistency measurements. It also provides checks of the gantry speed, and gantry/multileaf collimator synchrony all within 6 minutes.*

KEY WORDS: *Dose rate, Quality Assurance, Tomotherapy.*

□ Controlli quotidiani di qualità della tomoterapia

RIASSUNTO: *Un fantoccio ed il software specificatamente dedicato sono usati per i controlli quotidiani di qualità delle caratteristiche del fascio radiante della tomoterapia Hi-Art. Sia il fantoccio che il software associato forniscono le valutazioni dell'output rotazionale e dell'intensità dell'energia. Permettono anche il controllo della velocità del gantry e della sincronizzazione gantry/collimatore multilamellare, il tutto entro 6 minuti.*

PAROLE CHIAVE: *Rateo di dose, Controllo qualità, Tomoterapia.*

□ INTRODUCTION

The majority of treatments delivered by conventional radiation machines are delivered using a step and shoot fashion, where beams are delivered with the linear accelerator fixed at one angle for each beam. Unlike conventional radiation treatment machines, the helical tomotherapy machine delivers all radiation treatments in a helical fashion, where the linear accelerator is continuously rotating around the patient. The shape of the beam changes continuously while rotating to conform to the target's shape from different angles. To insure that the right radiation dose is delivered, the output of linear accelerators is checked on a daily basis.

For conventional linear accelerators, the output is typically checked with a flat array of detectors with the beam incident from one angle. Since the tomotherapy machine delivers the treatment while continuously rotating, the output should be measured in the same manner as the treatment delivery, together with the fact that the tomotherapy is a sole Intensity Modulated Radiotherapy Treatment (IMRT) machine necessitates the need for new means and equipment to make the appropriate Quality Assurance (QA) procedure.

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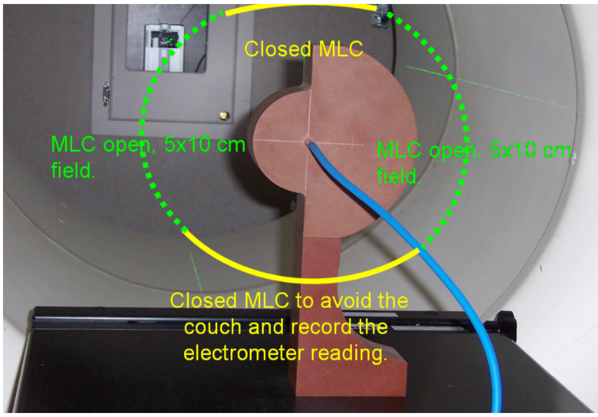

Figure 1. The QA phantom set-up for tomotherapy machine daily QA.

The phantom and procedure detailed in the material and methods section provide the means to check the consistency of multiple machine characteristics in one procedure. These characteristics include: the machine output, energy, gantry angular position and synchrony between the Multi Leaf Collimator (MLC) with the gantry rotational speed.

☐ MATERIALS AND METHODS

■ **PHANTOM.** A phantom made of water equivalent solid water (*Gammex, Middelton, WI*) which is designed as two co-axial semi-cylinders with different radii. The phantom is supported on stand made out of the same solid water material. The phantom used at the University of Wisconsin has 5.0 and 10.0 cm radii and 6.0 cm wide semi-cylinders, fitted on top of a 16.0 cm high stand. The height of the stand is carefully selected so that when the phantom is set-up on the treatment couch, with the couch at its lowest allowed treatment position, the axis of the phantom is aligned with the gantry axis. The phantom is designed to hold two ion A1SL ion chambers (*Standard Imaging, Madison, WI*). The first ion camber is positioned at the center of the phantom, while the second is 15 cm off center. In testing position, the ion chambers are connected to the TomoElectrometer (*TomoTherapy Inc. Madison, WI*). TomoElectrometer is an 8-channel electrometer that is capable of measuring dose and dose rate with an integration period as small as 100 millisecond. Center lines are marked on at least three faces of the phantom to indicate the center of the phantom and to be used with conjunction with the room lasers for easy quick setup. Figure 1 shows the phantom aligned at the virtual isocenter of the tomotherapy machine.

■ **SET-UP.** The compact size of the phantom makes it easy to set-up. The lines on the three faces of the phantom that intersect at the center of the phantom are aligned to the room lasers. The A1SL ion chambers are inserted at the center of the phantom. Set-up time is less than a minute.

■ **PROCEDURE.** The radiation procedure uses a 5 cm (inferior-superior) by 10 cm lateral field. The gantry completes 3 rotations at one rotation per minute while the beam is turned on. The MLC leaves that correspond to 5 x 10 cm field will open for an arch of 120 degrees on each side of the phantom and then close after each 120 degree arch to allow enough time for the user to record the electrometer reading after each open field segment. At the end of the three gantry rotations, the six electrometer readings will be used by a computer program to calculate the dose output for each segment.

■ **ANALYSIS.** As a check of the consistency of the machine's output, the average of the three segments that correspond to the 5 cm radius of the phantom is compared to a nominal value obtained as a reference value during the commissioning of the machine or during an annual QA. To check the consistency of the machine's energy, the ratio of the average output from the 10 cm side of the phantom to the average output from the 5 cm side of the phantom is calculated and compared to the nominal ratio obtained during commissioning or during an annual QA. Since the shape of the phantom is not symmetric around the gantry's rotation axis, the output reading from each segment is sensitive to changes in the gantry angular position. This provides a check on the gantry's angular position. The synchrony between the MLC and the gantry rotational speed is very essential for the helical tomotherapy treatment delivery. A procedure to check this synchrony is typically scheduled on a quarterly or annual basis. With this phantom, this check is now done on a daily basis. The shape of the phantom together with the programmed MLC leaves opening and closing times provide a check on the synchrony of the MLC with the gantry rotational speed.

■ **SOFTWARE.** The user collects the electrometer cumulative charge reading every 30 seconds during the closed MLC segment, and enters it into a computer program. The program calculates the charge collected during each of the six segments. The output from three segments that correspond to 5 cm depth are used to check the output consistency. While the output from the 10 cm depth divided by the output from 5 cm depth is used for energy consistency check. Figure 2 shows a sample calculation sheet.

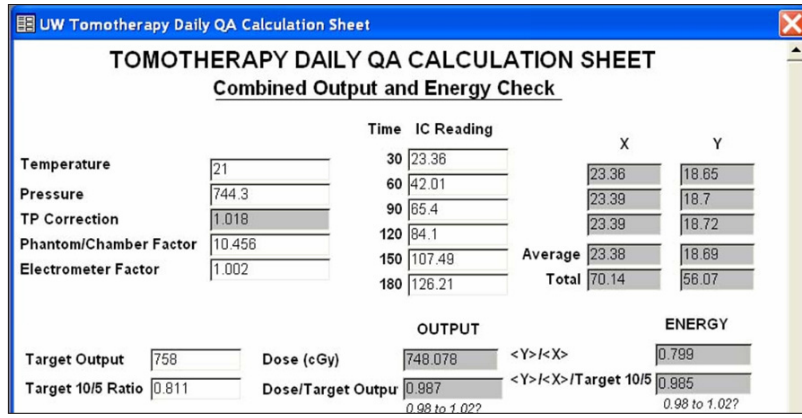

Figure 2. Sample daily QA sheet. The X column contains the 3 ion chamber readings and average corresponding to the 5 cm depth, while the Y column shows those from the 10 cm depth.

☐ CONCLUSION

The presented phantom allows for a daily check of essential characteristics of the tomotherapy machine.

These characteristics include the consistency of output, energy, gantry angular position and synchrony of MLC and gantry rotational speed.

All these checks can be done within 6 minutes. Without this phantom, the output and energy consistency used to take at least 20 minutes.