Quality Assurance of Pinnacle Treatment Planning System for External Beam Radiotherapy

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Abstract – **Introduction: A quality assurance (QA) program for two Pinnacle version 7.0 workstations was developed and implemented.**

Materials and methods: The program consisted of periodic test procedures which were designed according to the IAEA recommendations for treatment planning system (TPS) quality assurance. The TPS features tested were hardware, transferred CT images, and critical software functions. The hardware tested was CPU, digitizer, printer, and backup devices. Consistency of CT images of 3d01a and CIRS phantoms transferred to Pinnacle was examined, i.e. patient orientation, image geometry, tissue density, and contour dimensions. The aspects of Pinnacle software evaluated were monitor unit and dose calculation, plan printout data and electronic plan transfer. Photon dose calculations were verified against doses measured with a Farmer chamber. For electron beams, Pinnacle and manual calculations were compared.

Results: Test results for hardware functionality were satisfactory. Patient orientation was properly represented in CT images in Pinnacle. Image geometry and contour dimensions were acceptable. However, the reported densities in Pinnacle differed from the actual density values by more than 0.02 g/cm^3 for low (ρ≤0.28 g/cm^3) and high-density (ρ≥1.362 g/cm^3) inserts of the 3d01a phantom. Similar discrepancies were observed in the lung, adipose, solid water, and bone inserts of the CIRS phantom. Moreover, calculated doses in Pinnacle exceeded tolerance in some points in the CIRS phantom.

Discussion: Erroneous tissue densities in Pinnacle most likely contributed to the discrepancies in calculated doses. Thus the CT number-density calibration curve must be corrected and dose measurements repeated to resolve the dose calculation inaccuracies. Electron dose calculations also need to be verified with measurements. Initial implementation of the QA program verified the capabilities of Pinnacle and was a marked improvement on the overall treatment planning process. Periodic testing would have to be followed to ensure that the Pinnacle workstations consistently meet the desired quality.

Keywords – **treatment planning, quality assurance**

I. INTRODUCTION

The complexity of the treatment planning process in radiotherapy makes it necessary to develop a quality assurance process which will maintain the desired accuracy and minimize errors in treatment planning.

Treatment planning for external beam radiotherapy is currently being done on two Pinnacle ver. 7.0 (Philips Healthcare, Andover, MA, USA) workstations. Both are capable of three-dimensional planning using CT images and are able to calculate the dose using convolution-superposition dose calculation algorithm for photon beams and using pencil beam algorithm for electron beams.

To verify the accuracy of treatment plans generated from the two workstations, a QA program was developed. The program aimed to test hardware and software functionalities of the TPS. It also intended to identify sources of uncertainty in the treatment planning process, namely input of CT data and contours, dose calculation, electronic plan transfer and data backup. The IAEA documents, TRS 430 and TECDOC 1583 [1, 2], were used as guides in designing the program. The tests were designed to be done periodically to track TPS performance. However, because the TPS workstations were being tested for the first time, initial tests conducted were similar to acceptance and commissioning tests as outlined in the IAEA documents [1, 2].

II. MATERIALS AND METHODS

The QA program is divided into three parts, each of which tests the following features of the TPS – input and output hardware, CT anatomical information, and external beam software. Tables 1, 2 and 3 show the tests in the QA program as well as their frequencies and tolerances. The tests were conducted during the initial implementation of the QA program.

A. *Hardware*

The hardware tests, as described in Table 1, were performed. The CPU of each workstation was tested by rebooting the TPS and observing for any on-screen error messages. The digitizer test was done by inputting several manually drawn contours. The dimensions of the contours

Table 1. TPS hardware tests, with frequencies and tolerances.

Test	Description	Frequency	Tolerance
CPU	The CPU, memory, and hard disk must be functioning properly	Daily	No diff
Digitizer	The digitizer sensitivity should not have drifted	Monthly	0.2 cm
Printer	The printer scaling must not have drifted.	Quarterly	0.2 cm
Backup recovery	The data backed up in the hard disk, in the magnetic tape and the optical disk must be recovered.	Quarterly	No diff

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Table 2 Anatomical information QA tests, with frequencies and tolerances.

Test	Description	Frequency	Tolerance
CT scan transfer	The CT transfer protocols must not change. The L-R, ant.-post., and sup.-inf. Directions must be properly labeled.	Patient specific	No diff
CT geometry and density check	The relationship between the CT number and geometry must not change. Dimensions and densities of the CT images of the phantom must agree with actual values.	Quarterly and after major repairs on CT sim	Distances: 0.2 cm Densities: 0.02 CT no.: 20
Patient anatomy	Patient anatomy representation must not change. Dimensions of contours of phantom objects in the TPS must agree with actual object dimensions.	Quarterly	0.2 cm

on the TPS must agree within 0.2 cm of the actual dimensions of the manual contours. For the printer test, the contour printouts were compared to those of the manual contours. Retrieval of backed-up plans was tested by taking note of any major changes in the retrieved plan data (e.g. beam energy, monitor units, isodose line display) compared to the original archived plan data.

B. Anatomical Information

Anatomical information tests, as summarized in Table 2, were done by scanning the 3d01a phantom and the CIRS thorax phantom model 002LFC (Computerized Imaging Reference Systems, Norfolk, Virginia, USA), shown in Fig. 1, in two CT scanners –Somatom Emotion and Somatom Sensation (Siemens AG, Munich, Germany). The images were then transferred to Pinnacle. In the CT scan transfer test, an anterior-superior radiopaque marker was placed on the phantom. The marker was examined in the images in Pinnacle to check if the patient orientation was properly represented.

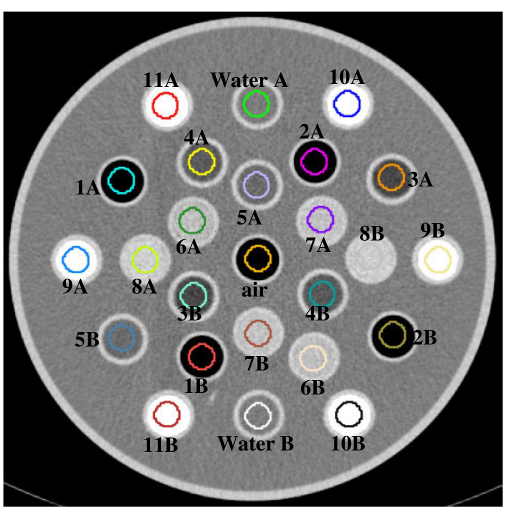

Fig. 1 CT image of the 3d01a phantom showing water, air, and various other density inserts labeled 1-11.

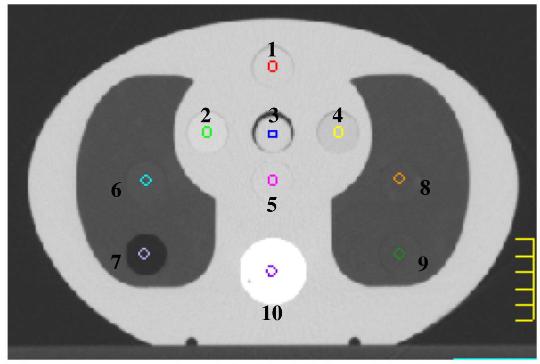

Fig. 2 CT image of the CIRS Thorax phantom with different tissue-equivalent plugs – 1 & 5: Plastic water (1.04 g/cm^3), 2: muscle (1.06 g/cm^3), 3: water-filled syringe (1.00 g/cm^3), 4: adipose (0.96 g/cm^3), 6, 8 & 9: lung (0.20 g/cm^3), 7: air (0.001 g/cm^3), 10: bone (1.60 g/cm^3)

In the CT geometry and density check, the CT number-

Table 3 TPS software QA tests, with frequencies and tolerances

Test	Description	Frequency	Tolerance
Revalida-tion	Generate test plans for photon and electron beams in the TPS using phantom CT images. Include various features of the software, e.g. inhomogeneity corrections, MLCs, wedges, etc. Initial plans serve as benchmark data. For subsequent testing, compare with benchmark data.	Annually	No diff
MUs and dose calc.	MUs calculated in the test plans created TPS must agree with those in the benchmark plans. When the test plans are delivered on the phantom, the calculated dose must also agree with the measured dose.	Annually	MU: No diff Dose: 2–4% (photons), 3% (electrons)
Plan details	Plan details in the printout must be the same as those in the TPS	Patient specific and Monthly	No diff
Electronic plan transfer	Plan details must not change during electronic plan transfer to Record and Verify system and to another TPS workstation.	To R&V: patient specific To TPS: Monthly	No diff

Table 4 Densities of inserts in the 3d10a phantom.

Insert	Density (g/cm^3)	Insert	Density (g/cm^3)
Air	0.001	6A and 6B	1.095
1A and 1B	0.020	7A and 7B	1.100
2A and 2B	0.280	8A and 8B	1.110
3A and 3B	0.910	9A and 9B	1.215
4A and 4B	0.940	10A and 10B	1.362
5A and 5B	0.975	11A and 11B	1.475
Water	1.000		