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Anatomical Information Quality Control of a Radiotherapy Treatment Planning System

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ABSTRACT

Introduction: To determine radiotherapy accuracy and prevent treatment errors, quality assurance is crucial during the planning phase of radiation therapy. Therefore, the goal of this study was to create criteria for the routine quality control assessment of radiation treatment planning systems TPS to assess their effectiveness and accuracy.

Material and Methods: In this study, we used a Prowess Panther treatment planning system TPS (version 5.51), a Siemens model Somatom Confidence computed tomography simulator, an anthropomorphic Alderson-Rando phantom, and a density phantom made from a CTDI head phantom by inserting plugs that mimicked human tissue. The TPS features include hardware, transmitted CT images (anatomical information), and key software operations; however, in this investigation, we focused exclusively on the tests involving anatomical information.

Results: The Prowess Panther RTPS version 5.51 workstation consistently met the requisite quality where all results of the radiation treatment planning systems (Prowess Panther RTPS) anatomical information tests were satisfactory and acceptable.

Conclusion: By averting several radiation-related events, the recommendations for TPS CT image quality control testing made in this study will assist to increase the safety and effectiveness of cancer radiotherapy.

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Introduction

With the quick advancement of medical technology and high-precision radiation therapy techniques, radiation therapy plays a significant role in the treatment of cancer, and the quality of life of cancer patients is progressively improving [1].

The Radiation Treatment Planning (RTP) process is a crucial part of radiation therapy, is multi-step and complicated, the diagnosis of the patient is the first step, followed by a decision on radiation [2], and is normally carried out with the assistance of a treatment planning system (TPS) [3]. TPS is a computerized system that uses a dose computation algorithm to determine the dosage distribution for photon and electron beams [4]. The administration of the specified dose to the target volumes while limiting the dose to the nearby normal tissues or organs at risk forms the basis of effective treatment planning for each patient [3].

Quality control in radiotherapy is upheld throughout the entire radiotherapy process and incorporates all staff groups in a cooperative manner [5]. For safe and effective medication delivery, dose estimations must be precise [6].

There aren't many early reviews on TPS's quality assurance (QA). The first of these was a study by McCullough and Krueger in 1980 [7], and Van Dyk et al. presented the first committee findings from Canada in 1993 [8]. The American Association of Physicists in Medicine (AAPM) Task Group Report 65 in 2004 [10] provided a detailed description of the dose calculation algorithms used by TPS, the AAPM Task Group Report 53 in 1998 [11] provided guidelines for users and vendors on QA for radiation therapy planning, and the International Commission on Radiation Units and Measurements (ICRU) Report 42 in 1987 [9] provided an early international report on TPS. The safety standards for TPS producers were outlined in the International Electrotechnical Commission (IEC) report No. 62083 in 2000 [12]. The commissioning and quality assurance (QA) of TPS was the subject of publications by the International Atomic Energy Agency (IAEA) [2] and the European Society of Therapeutic Radiation Oncology (ESTRO) [13] in 2004.

The IAEA created a report for the commissioning of TPS in 2008 [14], while the Netherlands Commission of Radiation Dosimetry (NCS) also published a handbook for TPS in 2006 [15].

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The QA of TPS has been the subject of numerous reports from domestic and international organizations in recent years. The most current report is titled Software Engineering and Formal Methods (SEFM) in 2021 [16]. The IAEA Technical Report Series No. 430 (TRS-430), which aimed to serve as a manual for the full range of TPS encountered globally, is the most thorough of all these papers.The IAEA divided periodic quality control (QC) tests of the TPS into basic three parts, tests for TPS features hardware, software, and data transfer, and these should be implemented periodically [2, 14].

Many major incidents have occurred in the past as a result of the lack of thorough TPS QA procedures. As a result, To determine radiation accuracy and prevent treatment errors, quality assurance in the radiotherapy planning process is essential [17].

The main objective of this work was to check the performance and accuracy of the radiation dose calculations of the Prowess Panther treatment planning system workstation by implementing QC tests of Prowess Panther, and we will focus only on CT anatomical information features in detail.

Materials and Methods

Materials

The Prowess Panther treatment planning system TPS, version 5.51, Build 4608 (Prowess Inc., Concord, CA, USA) was the equipment used in this study.

b. Siemens model Somatom Confidence with serial number S. N. 100343, a computed tomography simulator.

c. Anthropomorphic Alderson-Rando Phantom (ART): The international benchmark for radiation therapy quality control. It is divided into 36 identical slices, each 2.5 cm thick and numbered. The orifices on each slice are spaced 3 or 1.5 cm apart, depending on the slice. It measures 1.73 meters (5 feet 8 inches) in length, weighs 73.5 kg (162 pounds), and has a 3-centimeter thick top.

d. Density Phantom: CTDI head phantom, PTW FREIBURG, containing many plugs as human tissue-mimicking materials with different relative electron densities.

All devices are installed in at Radiotherapy Unit at the Clinical Oncology & Nuclear Medicine Department, Faculty of Medicine, and Mansoura University, Egypt.

Methods

The periodic quality control QC tests for CT anatomical information are outlined in Table 1 by the recommendations given in the International Atomic Energy Agency IAEA's Commissioning and Quality Assurance of Computerised Treatment Planning Systems for Radiation Treatment of Cancer, Technical Reports Series Number 430 [2] and the IAEA technical document number 1583 [14]:

Test 1: In the Transfer of the CT scan test, an anterior-posterior(AP), left-right, and superior-inferior radiopaque markers were placed on the nose and left ear of the humanoid Alderson-Rando phantom and beam modifier (bolus), which was scanned by a CT- simulator machine at Parameters (120 KV& 213 mA and slice thickness were 1mm), and the images then were transferred to Prowess TPS, To ensure that the patient orientation was accurately represented, the markers in the photographs in the Prowess workstation were reviewed.

Test 2: In the test of CT geometry and density, the density phantom was used to determine the CT number-electron density calibration curve suitable for the CT simulator with scan protocol at Parameters (120 KV& 213 mA). Using TPS techniques, the diameters, and densities of the inserts in the density phantom's CT images were measured and contrasted with actual values. The CT pictures of the density phantom's dimensions and densities must match up with actual values.

Test 3: In the test of patient anatomy, using the TPS delineation tools in the Prowess workstation, circular outlines were manually created around features on CT images of the Alderson-Rando phantom. A few Phantom structures' actual dimensions were measured and contrasted with those of phantom incisions on the TPS. The proportions of the outlines of phantom structures in the TPS must match the phantom's actual dimensions.

All the data obtained should be documented, if any result was out of tolerance it was necessary to stop working on the TPS and contact the biomedical engineer responsible for maintenance.

Table 1. Tests of TPS anatomical information, purposes, frequencies, and tolerances
*Quarterly=every 3 months

	Test	Purpose	Frequency	Tolerance
1	Transfer of CT scan	To ensure that the CT transmission protocols remain unchanged.	Patient-Specific	No difference
2	CT geometry and density check	To ensure that the geometry of the image and the CT number and density are still related.	*Quarterly & after major CT-simulator maintenance	CT no.: 20, Distances: 2 mm, Relative electron densities: 0.02
3	Anatomy of Patient	To check that representation of patient anatomy has not changed.	*Quarterly	2 mm

Results

CT scan transfer test

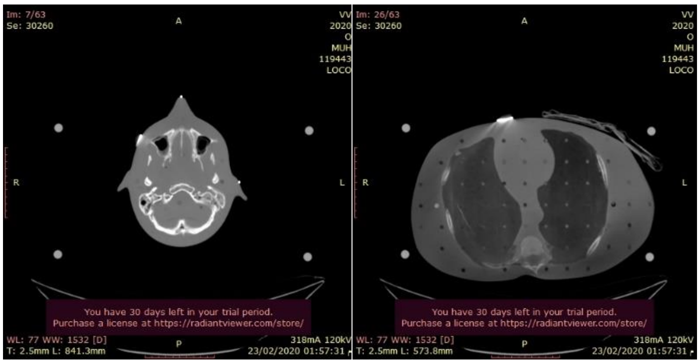
We ensured that the CT transfer protocols to Prowess Panther TPS remained unchanged, in which all markers and beam modifiers (bolus) were transferred in the same place as in Figure 1 (a, b). The anterior-posterior, left-right, and superior-inferior directions were labeled properly and CT-scan data were imported correctly to the Prowess Panther TPS as in Figure 2 (a, b).

Test of CT geometry and density check

The CT image is displayed on the TPS as a relative electron density (RED) mapping, using the conversion curve from CT number to RED. The CT scanner may have deviated from its baseline performance characteristics, leading to significant errors in the dose distribution calculation, as shown by the drift in the conversion curve. As a result, the TPS must be recalibrated with a new CT number-density conversion curve, using the CT images of the density phantom.

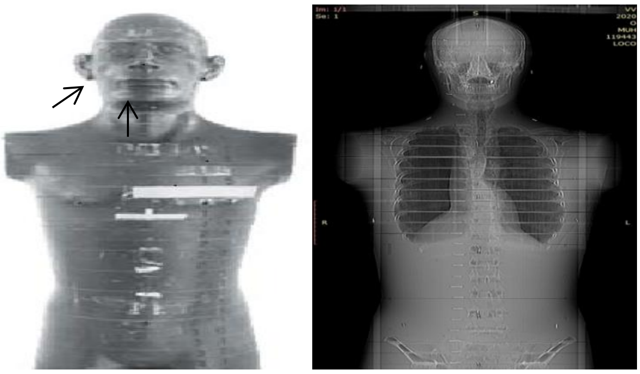
The inserts' diameters in the CT images of the density phantom were calculated using the Prowess measurement tools and were the same as the actual values; Figure 3 **(**a,b).

The TPS estimates the densities for inserts as it is defined. The defined densities of bone, muscle, soft tissue, water, fat, lung-mimicking materials, and air, are nearly equal to that calculated on the TPS, and the relative difference was ≤0.02. The defined and calculated densities of the inserts and the relative differences are given in Table (2) and Figure (4).



(a) (b)

Figure 1. (a) CT-scan axial slice of Rando phantom with marker on nose and left ear, and (b) CT-scan axial slice of Rando phantom with bolus

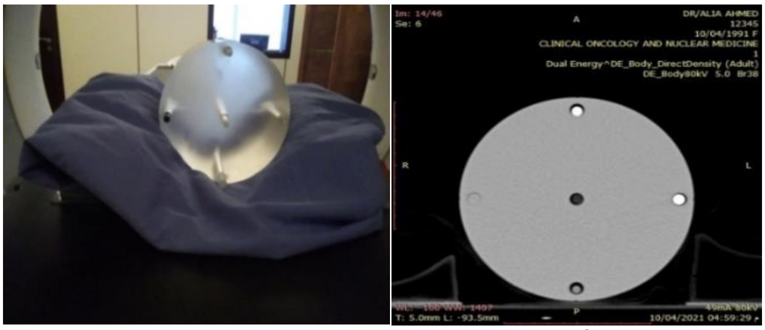


(a) (b)

Figure 2. (a) The anterior-posterior, left-right, and superior-inferior directions of the humanoid Alderson-Rando phantom (b) CT-scan coronal view of the phantom with the same directions

Table 2. The plugs used as human tissue-equivalent materials in the density phantom

Insert	Density (gm/cc)	Density value on TPS	Relative Difference (%)	CT number
Teflon (Bone)	2.11	2.10	0.01	1005
Acrylic (Muscle)	1.163	1.178	-0.015	54
Polystyrene (Soft tissue)	1.03	1.024	0.006	25
Water Syringe (Water)	0.997	0.999	-0.002	-5
Polyethylene (Adipose)	0.93	0.95	-0.02	-74
Wood (Lung exhale)	0.45	0.455	-0.005	-561
Cork (Lung inhale)	0.24	0.223	0.017	-780
Air (Air gaps)	0.001	0.001	0	-1000



(a) (b)

Figure 3. (a) And (b) Density phantom fabricated from CTDI head phantom with multiple plugs with different densities and its CT image respectively

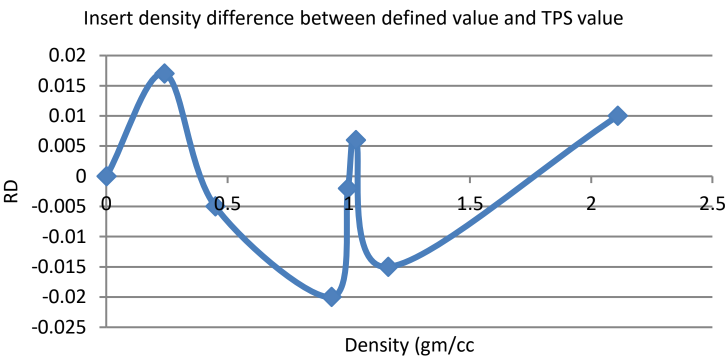
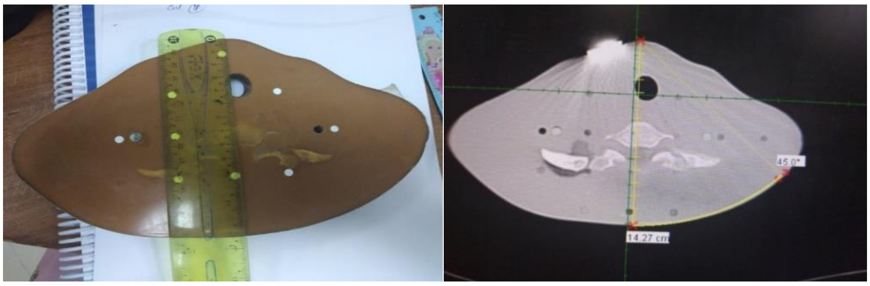


Figure 4. The relative difference between defined values and calculated values by Prowess measurement tools of densities of the inserts. The horizontal curve represents tolerance values of 0.02 gm/cc



(a) (b)

Figure 5. (a) And (b) Transverse cut from the real image and the CT image of the Alderson-Rando phantom respectively

Test Patient anatomy

The patient's anatomical representation was left unchanged. Dimensions of contours of phantom objects calculated with Prowess measurement tools agree with the actual dimensions measured on the phantom (within 0.2 cm of actual value).

In the head and neck region, all comparisons were acceptable, for example: for cut No. 9, the measured and calculated lengths from anterior to posterior were 14.25 cm and 14.27 cm respectively; Figure 5 (a) and (b).

In the chest region, for cut No. 11 as an example, the measured and calculated lengths from anterior to posterior were 16.5 cm and 16.60 cm respectively. The measured and calculated widths were 39.7 cm and 39.56 cm respectively. The measured and calculated lengths of the left lung from anterior to posterior were 10.8 cm and 10.80 cm respectively. The measured and calculated widths of the right lung were 8.5 cm and 8.39 cm respectively.

In the abdomen region, for cut No. 22, the measured and calculated lengths from anterior to posterior were 21.1cm and 21.08 cm respectively. The measured and calculated widths of vertebrae were 3.9 cm and 3.91 cm respectively.

In the pelvis region, for cut No. 33, the measured and calculated lengths from anterior to posterior were 18.9 cm and 18.82 cm respectively. The measured and calculated widths were 32.8 cm and 32.73 cm respectively. The measured and calculated lengths of vertebrae were 1.91cm and 1.91cm respectively.

Discussion

The TPS produced satisfactory results with correct measurements and patient orientation, passing all tests used to verify anatomical information. According to our research, the Prowess Panther TPS can plan in three dimensions using CT scans and determine the dosage distribution using an algorithm for convolution superposition dose calculation for photon beams. A QC program was created to ensure the treatment plan produced by the RTPS was accurate. The program was designed to examine the specific input of CT data and contours.

In a test of CT scan transfer, If any change in directions and labels was exist (change in patient geometry), it would cause a big mistake in irradiation on the megavoltage teletherapy machine, causing overexposure or underexposure accidents.

In a test of CT geometry and density check, there was no drift in CT number-relative electron density calibration curve baseline and all values were in tolerance. If the density values are out of tolerance, this implies that a new CT number-density conversion curve must be used to recalibrate TPS.

In a test of Patient anatomy, In all body regions, the comparisons between measured and calculated dimensions are all acceptable. If any result is out of tolerance, it indicates anatomical representation errors hence dose distribution calculation errors.

It is vital to design a quality assurance procedure that will maintain the intended accuracy and reduce errors in the treatment planning process due to the complexity of the treatment planning process in radiation. The medical physicist is in charge of the TPS's quality assurance and the use of its output.

In quality control tests we measure the performance of the TPS associated with specifications and then compare the measurement with the specification. The results of Successful periodic tests will be compared to the results of the initial tests performed after commissioning. If the measurement falls outside the specification (out of tolerance), it is unacceptable and corrective action is required [2 and 14].

On two Pinnacle TPSs version 7.0 workstations, R.Z.J. Remoto and J.D. Corpuz (2013) conducted the anatomical information tests; all results were satisfactory, except the CT density test, where the TPS overestimated densities for inserts with densities below 0.280 gm/cc and underestimated densities for inserts above 1.362 gm/cc for the Sensation CT scanner [4]. In our study, all measurements are acceptable and need no corrective actions. If the result values were near to being out of tolerance, we would need to contact the biomedical engineer to avoid future errors or breakdowns.

Conclusion

The Prowess Panther TPS version 5.51, Build 4608, passed all the anatomical information tests, and the CT images function optimally. Periodic quality control testing of the TPS improves the quality of radiation treatment, so the Prowess workstation would have to be tested periodically by the CQMP responsible for the RTPS at any radiotherapy center to guarantee that treatment plans consistently meet the specified level of excellence.

References

1. Oh Y, Shin DO, Kim J, Kwon N, Lee SS, Choi SH, Ahn S, Park DW, Kim DW. Proposal on guideline for quality assurance of radiation treatment planning system. Progress in Medical Physics. 2017 Dec 31;28(4):197-206.
2. Van Dyk J, Rosenwald J-C, Fraass B. International Atomic Energy Agency IAEA. Commissioning and Quality Assurance of Computerized Treatment Planning Systems for Radiation Treatment of Cancer. Technical Reports Series No.430, IAEA, Vienna, Austria. 2004.
3. Aly MM, HaniNegm S, Fouad[1] A. Quality Assurance of Three Dimensional Treatment Planning System For External Photon Beam Radiotherapy. IOSR Journal of Applied Physics. 2017;9(3):125-33.
4. Remoto RZ, Corpuz JD. Quality Assurance of Pinnacle Treatment Planning System for External Beam Radiotherapy. World Congress on Medical Physics and Biomedical Engineering IFMBE Proceedings.2013;39:1876–9.
5. El-Ghamrawi K, Seleem A, El-Haddad M, Mahmoud E. Quality Management System in radiotherapy needs and requirements. Research in Oncology. 2011 Jan 1;7(1-2):1-5.
6. Smilowitz JB, Das IJ, Feygelman V, Fraass BA, Kry SF, Marshall IR, et al. AAPM medical physics practice guideline 5. a.: commissioning and QA of treatment planning dose calculations—megavoltage photon and electron beams. Journal of applied clinical medical physics. 2015 Sep;16(5):14-34.
7. McCullough EC, Krueger AM. Performance evaluation of computerized treatment planning systems for radiotherapy: external photon beams. International Journal of Radiation Oncology* Biology* Physics. 1980 Nov 1;6(11):1599-605.
8. Van Dyk J, Barnett RB, Cygler JE, Shragge PC. Commissioning and quality assurance of treatment planning computers. International Journal of Radiation Oncology* Biology* Physics. 1993 May 20;26(2):261-73.
9. International Commission on Radiation Units and Measurements (ICRU). Use of computers in external beam radiotherapy procedures with high-energy photons and electrons. Report 42: Bethesda. 1987.
10. Papanikolaou N, Battista JJ, Boyer AL, Kappas C, Klein E, Mackie TR, et al. Tissue inhomogeneity corrections for megavoltage photon beams. (No Title). 2004.
11. Fraass B, Doppke K, Hunt M. Quality assurance for clinical radiotherapy treatment planning. American Association of Physicists in Medicine (AAPM) Radiation Therapy Committee Task Group 53, Medical Physics Journal. 1998; 25:1773–829.
12. International Electrotechnical Commission (IEC). Medical electrical equipment requirements for the safety of radiotherapy treatment planning systems. IEC 62083 (2000-11). Geneva. 2000.
13. Mijnheer B, Olszewska A, Fiorino C, Hartmann G, Knöös T, Rosenwald JC, et al. Quality assurance of

treatment planning systems: practical examples for non-IMRT photon beams. Brussels: Estro; 2004.

14. International Atomic Energy Agency (IAEA). Commissioning of Radiotherapy Treatment Planning Systems: Testing for Typical External Beam Treatment Techniques. IAEA-TECDOC-1583, IAEA, Vienna, Austria. 2008.
15. Bruinvis IA, Keus RB, Lenglet WJ, Meijer BJ, Mijnheer BJ, van′t Veld AA, et al. Quality assurance of 3-D treatment planning systems for external photon and electron beams. NCS Report. 2005 Mar;15.
16. García Romero A, Hernández Masgrau V, Baeza Trujillo M, Teijeiro García A, Clemente Gutiérrez F, Morera Cano D. Results of the survey of the Spanish Society of Medical Physics on the quality control of treatment planning systems in the field of photon and electron beams of external radiotherapy. Rev Fis Med. 2021; 22(2): 55-66.
17. Özgüven Y, Yaray K, Alkaya F, Yücel B, Soyuer S. An institutional experience of quality assurance of a treatment planning system on photon beam. Reports of Practical Oncology and Radiotherapy. 2014;19(3):195-205.