Sudan University of Science and Technology

College Of Graduate Studies

Assessment of Quality Control Procedures of the Treatment Planning System (TPS) At National Cancer Institute – Madani

تقييم إجراءات ضبط الجودة لنظام تخطيط العلاج بالاشعة في المعهد القومي للسرطان – مدني

A Thesis Submitted In Partial Fulfillment for the Requirements of M.Sc Degree in Medical Physics

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Dedication

To whom I loved and they loved me much more than I did, hoping that tomorrow will be better, smiley and fruitful in spite of all the expected obstacles.

Acknowledgment

I here find it of equity to appreciate the supervision, guidance and advice provided by Dr. Hassan Mohammed Ebraheem "research supervisor, the assistance and extreme co-operation I found in contact with Dr. Siddig Mohammed Ahmed Siddig, Mr. Abdulazeem Khaleefah, I have to report my highest appreciation to Dr.Fouzia Assadig of National Cancer Institute – Madani, thanks to Mr. Mustafa Mohammed Ahmed of RICK against his support who provide me with the core text, thanks to Dr. Mohammed Elfadil who pushed forward.

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Abstract

This study has been conducted at the medical physics department in National Cancer Institute – Madani to assess the applicability and performance of the quality control procedures of the treatment planning system (TPS). TPS trade name is "Plan W 2000". Data are collected with a form of adapted checklist used as an interview sheet.

Eight test procedures are assessed in relevance to the localized work needs of which four of them, resembling 50% are found as non-applicable due to lack of facilities where the other four procedures are performed in a modified time frequency.

Upon stated results the researcher conclude that there is NO standard QC protocol applied and referred to. the applied QC tests are performed upon need that arises accidentally in case of observed deviations and Treatment plans are verified by the work team (revision and checkup) prior to implementation.

At the end of the study report the researcher recommends to train a medical physicist in the field of QC for the TPS. the assigned medical physicist shall work to design a TPS protocol taking into account the features of applicability and performance in relevance to the work requirements in regard to universal standards.

ملخص الدراسة

أجريت هذه الدراسة في إدارة الفيزياء الطبية بالمعهد القومي للسرطان – مدني لتقييم مدى قابلية إجراءات ضبط الجودة للنظام المحوسب لتخطيط العلاج بالأشعة للتطبيق و التنفيذ ، يتم إستخدام برنامج إلكتروني معروف تجاريا بإسم "Plan W 2000". تم جمع البيانات باستخدام قائمة تحقق معدلة بغرض ملائمتها لهدف البحث.

بينت الدراسة أن أربعة من الثمانية الاختبارات اللازم إجرائها لا تجرى بسبب عدم توفر التسهيلات و قد مثلت نسبة 50% بينما يتم إجراء الاربعة الاختبارات الاخرى في غير المواقيت اللازم إجرائها فيها.

أستنتج الباحث عدم وجود بروتوكول معتمد محليا لإجراء الإختبارات، حيث يتم إجراء الاختبارات الممكن إجرائها و ذلك عند الحاجة المتمثلة في ظهور إنحرافات.

يتم التحقق من دقة تخطيط العلاج بالمراجعة التي يجريها أعضاء فريق العلاج الإشعاعي كلٍ من موقعه في عملية العلاج بالاشعة.

في نهاية الدراسة وضع الباحث توصيات تمثلت في تكليف إختصاصي فيزياء طبية ليكون مسؤلاً عن إجراء إختبارات ضبط الجودة للنظام الإلكتروني لتخطيط العلاج و المطبق في موقع هذه الدراسة بالإضافة إلى تكليفه بإعداد بروتوكول إختبارات ملائم لمتطلبات العمل في موقع الدراسة.

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List of abbreviations

Abbreviation	Description
QA	Quality Control.
ICRU	International Commission on Radiological Units and Measurements
DATA I/O	Data Input or Output.
WHO	World Health Organization.
AAPM	American Association for Physicists in Medicine.
ESTRO	European Society for Therapeutic Radiation Oncology.
NCS	Netherlands Commission on Radiation Dosimetry
COIN	Clinical Oncology Information Network.
IEC	International Electrotechnical Commission.
IPEM	Institute of Physics and Engineering in Medicine.
TPS	Treatment Planning System.
IAEA	International Atomic Energy Agency.
ICRP	International Committee for Radiation Protection.
SSRPM	Swiss Society for Radiobiology and Physics in Medicine.
QUASIMODO	Quality Assurance of Intensity Modulated radiation Oncology.
IMRT	Intensity Modulated Radiation Therapy.
CPU	Central Processing Unit.
DVDs	Digital Video Disks.
CT	Computerized Tomography.
Linac	Linear Accelerator.
UPSs	Uninterruptible Power Supplies.
QC	Quality Control.
UNIX	A trade name of computer operating system software.
SSD	Source Surface Distance.

TRS	Technical Reports Series.
QAP	Quality Assurance Program.
BEV	Beam Eye Views
DVH	Dose Volume Histogram

Chapter One

1.1-Intorduction:

Computerized treatment planning systems (TPSs) are used in external beam radiotherapy to generate beam shapes and dose distributions with the intent to maximize tumour control and minimize normal tissue complications .Patient anatomy and tumour targets can be represented as

3-D models. The entire process of treatment planning involves many steps and the medical physicist is responsible for the overall integrity of the computerized TPS to accurately and reliably produce dose distributions and associated calculations for external beam radiotherapy. The planning itself is most commonly carried out by a dosimetrist, and the plan must be approved by a radiation oncologist before implementation in actual patient treatments.

Treatment planning prior to the 1970s was generally carried out through the manual manipulation of standard isodose charts on to patient body contours that were generated by direct tracing or lead wire representation, and relied heavily on the judicious choice of beam weight and wedging by an experienced dosimetrist.

The simultaneous development of computed tomography (CT), along with the advent of readily accessible computing power from the 1970s on, led to the development of CT based computerized treatment planning, providing the ability to view dose distributions directly superimposed upon a patient's axial anatomy.

The entire treatment planning process involves many steps, beginning from beam data acquisition and entry into the computerized TPS, through patient data acquisition, to treatment plan generation and the final transfer of data to the treatment machine.

Successive improvements in treatment planning hardware and software have been most notable in the graphics, calculation and optimization aspects of current systems. Systems encompassing the 'Virtual Patient' are able to display

beam's eye views (BEVs) of radiation beams and digitally reconstructed radiographs (DRRs) for arbitrary dose distributions.

Dose calculations have evolved from simple 2-D models through 3-D models to 3-D Monte Carlo techniques, and increased computing power continues to increase calculation speed.

Traditional forward based treatment planning, which is based on a trial and error approach by experienced professionals, is giving way to inverse planning, which makes use of dose optimization techniques to satisfy the user specified criteria for the dose to the target and critical structures. Dose optimization is possible by making use of dose–volume histograms (DVHs) based on CT, magnetic resonance imaging (MRI) or other digital imaging techniques .

These optimized plans make use of intensity modulated radiotherapy (IMRT) to deliver the required dose to the target organ while respecting dose constraint criteria for critical organs.

Computerized treatment planning is a rapidly evolving modality, relying heavily on both hardware and software. Thus it is necessary for related professionals to develop a workable quality assurance programme that reflects the use of the TPS in the clinic and that is sufficiently broad in scope to ensure proper treatment delivery. (Podgorsak,F.B. et. al.2005)

1.2- Problem of study: -

Absence of information concerning the applicability and performance of periodic quality control tests in reference to locally adapted test protocol.

1.3- Objectives of study: -

1.3. a- General objective: -

To Assess quality control procedures of treatment planning system (TPS) applied in medical physics department at National Cancer Institute – Madani on basis of applicability and performance.

1.3.b - Specific objectives: -

1.3.b.1- To describe quality control procedures of treatment planning system (TPS) applied in medical physics department at National Cancer Institute - Madani.

1.3.b.2- TO assess applicability and performance of quality control procedures of treatment planning system (TPS) applied in medical physics department at National Cancer Institute - Madani.

1.3.b.3- To match the quality control procedures of treatment planning system (TPS) applied in medical physics department at National Cancer Institute – Madani with relevant test protocol.

1.3.b.4- To determine deviations of quality control procedures of treatment planning system (TPS) applied in medical physics department at National Cancer Institute - Madani if any.

1.4- Importance of study: -

The study is expected to provide data needed to decide either the treatment planning system applied in the department of physics at National Cancer Institute - Madani comply with standards to be followed or there are certain deviations that need recorrective actions to regain conformance with the standards.

1.5- Overview:

This study comprises five chapters classified as:

Chapter "One" contains the introduction, problem of study, study objectives and importance of the study.

Chapter "two" provide the literature revised by the researcher and contains two folds, the theoretical background which forms the conceptual framework of the study and the previous study which has been elected as the most relevant research material that dealt with the scope of this study.

Chapter "three" presents a concise profile of the methods and materials used.

Chapter "four" comprises the results.

Chapter "five" involves the discussion, conclusion and recommendations.

Chapter Two

2.1 Scientific background:

Quality control: -

Quality control' is the regulatory process through which the actual quality performance is measured, compared with existing standards, and the actions necessary to keep or regain conformance with the standards. Quality control is one part of overall quality assurance. It is concerned with operational techniques and activities used to check that quality requirements are met and adjust and correct performance if the requirements are found not to have been met.

Quality standards: -

' Quality standards' is the set of accepted criteria against which the quality of the activity in question can be assessed. Various national or international organizations, such as the World Health Organization (WHO) in 1988, AAPM in 1994, European Society for Therapeutic Radiation Oncology (ESTRO) in 1995 and Clinical Oncology Information Network (COIN) in 1999, have issued recommendations for standards in radiotherapy. Other organizations, such as the IEC in 1989 and the Institute of Physics and Engineering in Medicine (IPEM) in 1999, have issued recommendations for certain parts of the radiotherapy process. Where recommended standards are not available, local standards need to be developed, based on a local assessment of requirements. (podgorsak, E. B., 2005)

Quality assurance of the TPS

After the installation of a TPS in a hospital, acceptance testing and commissioning of the system is required, i.e., a comprehensive series of operational tests has to be performed before using the TPS for treating patients. These tests, which should partly be performed by the vendor and partly by the user, do not only serve to ensure the safe use of the system in a specific clinic, but also help the user in appreciating the possibilities of the system and

understanding its limitations. In the past some irradiation accidents happened with patients undergoing radiation therapy, which were related to the misuse of a treatment planning system.

Most often these accidents were not the result of system malfunctioning but due to a lack of understanding of how the TPS works. More details related to the incidence of accidents in radiotherapy can be found in several reports (IAEA 2000, IAEA 2001, ICRP 2001). In many of these accidents, a single cause could not be identified but usually there was a combination of factors contributing to the occurrence of the accident. The most prominent factors were deficiencies in education and training, and a lack of quality assurance procedures. Good training, as well as the availability of well-documented quality assurance procedures, therefore have a huge impact in preventing planning errors .

Over recent years, increased attention has been paid to quality assurance of treatment planning systems by various national and international organisations. Examples include Van Dyk et al.,1993, Shaw, 1996, SSRPM 1997, Fraass et al., 1998, Mayles et al., 1999, IAEA 2004 and NCS 2004. These reports provide recommendations for specific aspects of QA of a TPS, such as anatomical description, beam description and dose calculations. However, contrary to the situation for treatment machines, not many sets of practical recommendations for commissioning and QA of a TPS exist.

Although a lot of information is provided in these reports, it is difficult for a TPS user to decide which tests are absolutely necessary to perform by an individual user, and which tests the vendor or users groups of a specific system should perform. Also the number of tests provided by some of these reports is so overwhelming, that it would require a huge investment in manpower to perform the recommendations given in these reports. For those reasons departments with limited physics staff often choose for a pragmatic approach, thus doing only those QA tests they consider of direct importance for the use

of the new TPS in their departments. Particularly with respect to the 3-D aspects of planning systems, there are no clear guidelines which specific tests should be performed before the clinical use of a 3-D TPS can be started in a safe way. For that reason, it was decided during the 1999 ESTRO Physics Meeting in Göttingen, Germany, that ESTRO would start activities in the field of QA of a TPS.

It was emphasized that ESTRO would concentrate on those activities not yet covered by other groups or already described in other reports .

In August 2001 a project was funded by the European Communities, EC, started for a period of two years. The aim of that project was to increase the confidence level of clinicians for embracing optimised radiotherapy treatment regimens by making sure they can be achieved without an increase in severe side effects. One of the actions proposed for this purpose was to develop QA procedures for optimised radiotherapy planning and delivery, as outlined in the part of the project called QUASIMODO (QUality ASsurance of Intensity MODulated radiation Oncology). QUASIMODO will promote the safe introduction of advanced technology in RT by developing procedures for the QA of treatment planning systems, and by exploring new methodology for the verification of intensity modulated radiation therapy, IMRT .

From the review of national and international documents discussing QA of treatment planning systems it became clear that there is a need for a minimum number of tests. These tests should not only be suitable for small hospitals with limited resources, but are also needed by large (university) centers having a high patient load or limited staff. These tests should not be too cumbersome to perform and should cover the most essential parts of a TPS required for accurately planning of established conformal radiotherapy techniques. It should be realized, however, that the minimum number of tests to be performed in a specific institution depends very much on the local clinical practice.

The first aim of the QUASIMODO project was to identify a set of examples of tests for QA of treatment planning systems, easy to perform by users of different types of TPS .

A rapidly increasing number of institutions started with clinical implementation of IMRT. By varying the beam intensity over the treatment fields it is possible to deliver the radiation dose more conform to irregularly shaped target volumes. In this way it is possible to deliver a higher dose to the tumour while at the same time reducing the dose to surrounding healthy tissues. For the QA of these advanced techniques, general guidelines have been formulated by Ezzell et al. (2003). An interesting observation from a survey on the status of IMRT in Europe in 2002 was that almost every institution applied its own phantom/dosimetry system for the verification of treatment delivery. Obviously a specific solution was found in each institution, but no common approach or method was adapted at that time. It is the second aim of the QUASIMODO project to design tests and provide guidelines for the verification of IMRT. This second part of the QUASIMODO project is not only related to QA of treatment planning systems but includes QA of the treatment delivery as well. (Mijnheer, Ben et. al, 2004)

Acceptance testing:

A set of procedures carried out after delivery to confirm that the TPS works according to its specifications as documented at the moment of purchase.

Commissioning:

A set of procedures required bringing the new TPS or new software release into safe clinical operation. The TPS user should define the details of this procedure. The procedures include the introduction of geometric and dosimetric data into the system to define the treatment machine and its beams, and performing tests to learn how to use it, to verify the correct functioning of the entire software and to determine the limits of accuracy of the various calculations. (Mijnheer, Ben et. al, 2004)

Treatment planning system hardware:

The principal hardware components of a TPS include a central processing unit (CPU), a graphics display, memory, digitizing devices, output devices, and archiving and network communication devices. As hardware capabilities tend to change quickly, the general approach is to acquire equipment having the highest current specifications while allowing for future upgrades.

The CPU must have at least the memory and processor speed required by the operating system and treatment planning software. In particular, the specifications for the system speed, random access memory (RAM) and free memory, as well as networking capabilities, must be considered.

The graphics display is normally sufficient for accommodating the patient transverse anatomy on a 1:1 scale, typically 17–21 in. (43–53 cm) or larger. The resolution is submillimetre or better so as not to distort the input. Graphics speed can be enhanced with video cards and hardware drivers.

Memory and archiving functions are carried out through either removable media or networking. Removable media may include rewritable hard disks, optical disks or digital video disks (DVDs). Mass archiving may also be accomplished with slower digital audio tape (DAT) ;however, these devices have been reported to suffer from long term instability .

Archiving may be carried out over a network on a remote computer or server ; these archiving operations may be carried out automatically during low use periods of the day. Archiving operations can include beam data and parameters, patient related data such as CT scans and dose distributions, and data used for setting up the patient for treatment on a linac with record and verify systems.

Digitizing devices are used to acquire manually entered patient data such as transverse contours and BEVs of irregular field shapes. These devices are typically backlit tablets with either a magnetic or acoustic stylus for manually tracing shapes. Scanners, either flatbed or upright, can be used to digitize

images from hard copies such as paper or radiographic film. Video frame grabbers may also be used to digitize images.

Output devices include colour laser printers and plotters for text and graphics. Printers and plotters can be networked for shared access. Hard copies can be in the form of paper or film via a laser camera.

Uninterruptible power supplies (UPSs) are recommended for the CPU ,data servers and other critical devices, such as those used for storage and archiving. UPSs can provide backup power so that a proper shutdown of the computer can be accomplished during power failures of the regular power distribution grid, and they also act as surge suppressors for the power.

Communications hardware includes modem or Ethernet cards on local workstations and multiple hubs for linking various peripheral devices and workstations. Large networks require fast switches running at least 100 Mb/s for file transfer of images. Physical connections on both small and large networks are run through coaxial cable, twisted pairs or optical fiber , depending upon the speed requirements.

The environmental conditions under which the TPS hardware runs may be subject to temperature and humidity requirements. Thus the physical location of the equipment associated with the TPS within a department is of importance. (Podgorsak, F. B. et al.2005)

Periodic QC of treatment planning system:

Various QC checks are listed in (Table2.1 page 18), together with a reference to a test designed to perform each check and a suggested frequency of the test. Some of the tests are not applicable to TPSs with only basic planning capabilities, and the user should adjust the list in accordance with the features of the TPS.

QC test 1: Central processing unit:

Purpose:

To check that the CPU, memory, file systems and operating system are functioning optimally.

Procedure :

(a) Restart or reboot the computer as recommended by the vendor or as appropriate (UNIX based systems in particular can benefit from such a reboot).

(b) Observe onscreen messages during the reboot, to detect possible system malfunctions .

QC test 2: Digitizer

Purpose:

To check that the digitizer sensitivity has not drifted.

Procedure :

(a) Input a contour of known dimensions into the TPS in the normal way.

(b) Use a screen ruler to verify the correct dimensions. Agreement within 0.2cm is reasonable.

QC test 3: Plotter

Purpose:

To check that the plotter scaling has not drifted.

Procedure :

(a) Plot the contour from QC test 2 .

(b) Check the size against the input and previous plots. Agreement within 0.2cm is reasonable.

QC test 4: Backup recovery

Purpose:

To confirm that data that have been backed up can be recovered.

Procedure:

(a) Restore data that have been recently backed up (without overwriting current data).

(b) Check the integrity of the restored data. Depending on the TPS's backup utility, a separate procedure may be necessary for patient data, beam data and executables.

QC test 5: Computed tomography transfer

Purpose:

To check that CT transfer protocols have not changed.

Procedure:

Transfer four basic patient studies (prone, supine, head first and feet first). This can be done either on a phantom or on a patient with appropriate markers on the left, right, superior and inferior sides. If these tests are not done routinely, take extra patient labelling precautions (e.g. left–right, superior–inferior) for patients scanned by non-standard CT protocols.

QC test 6: Computed tomography density and geometry

Purpose:

To check that the relationship between the CT number and density and image geometry has not changed.

Procedure:

(a) Scan a phantom using a standard protocol (at least a single slice with known density inserts and geometry).

(b) Transfer the images to the TPS, use the TPS tools to measure densities and distances. Agreement within 0.2 cm is reasonable for distances. Agreement within 0.02 is reasonable for relative electron densities (i.e. CT numbers for a given object should not vary by more than ±20). If a significant change in the CT number is observed and cannot be eliminated by recalibration of the CT scanner, new CT number to electron density data need to be entered into the TPS. If CT data are input using film, geometric checks for scaling and distortion are necessary. Distortion may arise from either the CT filming process or the digitization process.

(c) Produce a film of the test phantom, making sure that the image contrast (level and window) is as before.

(d) Input the film in the usual way (e.g. by using a charge coupling device (CCD) camera or digital scanner). If the film digitization is used for inhomogeneity corrections, bulk densities are usually assigned manually. If the TPS automatically maps the digital matrix to densities, check that the densities are correct.

QC test 7: Patient anatomy

Purpose:

To check that patient anatomy representation has not changed.

Procedure :

(a) Use CT scans of a phantom with known dimensions of external and internal contours of objects (e.g. a square plastic phantom with cork inhomogeneity or a phantom with point landmarks)

(b) Use the automatic contouring capability to generate an external contour for the test phantom on multiple slices, and confirm agreement with the measurements for each slice.

(c) Generate an internal contour and confirm location, shape, etc., with known results. Use an appropriate CT image window width and level for all structures. If the TPS allows automatic contouring with different image zoom values, this function should be tested for each of these situations.

(d) If results are outside specifications, then one might look for:

(i) Differences of one or more CT pixels in contour locations relative to the CT data.

(ii) An incorrectly set threshold (or gradient) value on the automated contour tracking software, which can cause offsets of the contours, resulting in too large or too small volumes of a particular organ.

Users may have to define their own threshold values (for a given CT image type and given structure) to obtain the correct contours.

(e) Draw an external contour for a test phantom on multiple slices.

(f) Confirm agreement with the measurements.

(g) Draw internal contours and confirm the location, shape, etc., with known results. For all structures, use an appropriate CT image window width and level. Agreement within 0.2 cm is reasonable.

Issues:

(1) Precise agreement between the contours and the images from which they were derived should be looked for.

(2) Agreement between the contours and the known dimensions of structures should be looked for.

(3) Be aware that image zoom functions might disrupt this agreement.

(4)There might be differences of one or more CT pixels in the contour locations relative to the CT data.

(5) Incorrectly set CT display parameters (window and level) can cause the user to draw contours that generate too large or too small volumes of a particular organ. This is the biggest issue when creating accurate external surface and lung contours.

QC test 8: External beam revalidation

Purpose:

To check the constancy of external beam dose calculations to safeguard against inadvertent alteration or corruption.

Procedure:

= A check sum of all the data files will show whether any files have changed. If this cannot be done, an alternative is to review the directory that contains the data.

= Check the creation dates of files to ensure that none have been inadvertently altered. If the input data have been parameterized or processed, it is the most recent data that must be checked.

The raw data are of secondary importance, although they also should be maintained. The data can usually be inspected (reviewed) directly.

= Display and print the TPS configuration and calculation model parameters and check against the commissioning data.

= Owing to the complexity of modern TPSs, it is not practicable to check every pathway in every program for corruption, nor is it likely that such a failure will occur. However, it is good to have a standard set of plans that exercises a range of the software. It is recommended that each institution develop its own set of tests consistent with the techniques that it uses, based on the following broad principles:

(a) Look for reproducibility, not accuracy: the result of each test should be exactly the same as the original from the commissioning results. When software has been upgraded with new or improved algorithms, output from the new version becomes the benchmark.

(b) The test plans do not have to be good treatment plans: aim to test as much of the software as possible in a short time; for example, hard and dynamic wedges, blocks and MLCs, symmetric and asymmetric fields, with and without inhomogeneity corrections, etc., can be combined in a multi-beam plan. Only if a variation is detected is there a need to isolate its cause.

(c) Be aware of different options: if more than one algorithm is invoked or explicitly chosen under different conditions, test all that are used.

(d) Be sure to repeat the test plans from scratch, including the image transfer if possible, so that the entire process is checked, not just the dose calculation.

One example could be:

(1) CT slices through the thorax, inhomogeneity correction algorithm turned on.

(2) Anterior: low energy, 15 cm wide, symmetric, unwedged, unblocked.

(3) Right lateral: low energy, asymmetric (2 cm, 8 cm), 60°hard wedge, MLC.

(4) Posterior: high energy, 8 cm wide, symmetric, two shielding blocks.

(5) Left lateral: high energy, asymmetric (0 cm, 10 cm), 30°dynamic wedge, unblocked.

Similarly, another plan could be developed for electrons if these are use in the department, with and without bolus at low and high energy.

QC test 9: Monitor units/time

Purpose:

To check that there has been no change to the MU/time calculation of the TPS.

Procedure:

For the test plans from QC test 8, use the TPS to calculate the MUs/time and check for exact agreement with previous data.

QC test 10: Plan details

Purpose:

To check that the plan information shown on the hard copy has not changed

Procedure:

For the test plans from QC test 8, check that the isocentre co-ordinates, details of field size, SSD, wedges, blocking, etc., are printed out exactly as before.

QC test 11: Electronic plan transfer

Purpose:

To check that there has been no change to transfer protocols and data.

Procedure:

A standard set of test cases that exercises the most commonly used parts of the transfer process should be maintained. Again, this could be the output from plans from QC test 8. This set of test transfers should be run whenever data files, code, system software or other parts of the TPS and/or machine control systems are modified or updated.

QC test 12: Brachytherapy revalidation:

Purpose:

To check that there has been no change to brachytherapy dose distributions and time calculations.

Procedure:

Depending on the isotopes and techniques used, repeat brachytherapy tests 2, 6 and 7 (TRS 430 pages 177-181) to check that the brachytherapy dose distributions agree with the commissioning results and that treatment times are consistent with current activities and air kerma rates.

QC test 13: Plan details:

Purpose:

To check that the plan information shown on hard copy has not changed.

Procedure:

For the test plans from QC test 12, check that source co-ordinates, dose rates, dwell times, etc., are printed out exactly as before.

QC test 14: Independent dose and time check

Purpose:

To check that the TPS continues to calculate the dose and time correctly.

Procedure:

Depending on the isotopes used, repeat one or more of brachytherapy tests 3, 4 (pages 178-180 TRS 430) to check, in particular, that isotope activities and air kerma rates are still handled correctly.

QC test 15: Electronic plan transfer

Purpose:

To check that there has been no change to transfer protocols and data.

Procedure:

A standard set of test transfers should be run periodically and whenever data files, code, system software or other parts of the TPS and brachytherapy unit control systems are modified or updated. A subset of the cases tested during commissioning should be used for the testing of the transfer.

TABLE"2.1" example quality control checks and corresponding frequencies

Hardware: 1-CPU 2-Digitizer 3-Plotter 4-Backup recovery	Test	PS	W	M	Q	A	U
	QC test 1			Yes			Yes
	QC test 2		yes[a]	yes[b]			yes
	QC test 3				yes		yes
	QC test 4				yes		yes
Anatomical information: 1-CT (or other) scan transfer. 2-CTgeometry and density check. 3-Patient anatomy.	QC test 5	yes					yes
	QC test 6				yes		yes
	QC test 7	yes					yes
External beam software (for photons and electrons): 1-Revalidation (including MUs/time). 2-MUs/time. 3-Plan details. 4-Electronic plan transfer.	QC test 8	yes					yes
	QC test 9	yes					
	QC test 10	yes		yes			
	QC test 11	yes		yes		yes	yes
Brachytherapy:	QC test 12					yes	yes

1-Revalidation. 2-Plan details. 3-Independent dose and time check 4-Electronic plan transfer	QC test 13	yes					
	QC test 14	yes					
	QC test 15	yes		yes		yes	yes

PS: patient specific;

W: weekly;

M: monthly;

Q: quarterly;

A: annually;

U: after software or hardware update.

[a] Sonic digitizer.

[b] Electromagnetic digitizer.

(TRS 430, 2004)

In the publication titled "Quality control of treatment planning systems for teletherapy" by Swiss Society of Radiobiology and Medical Physics

a sample QC is laid down which differs somehow from the previous one, the publication stated that "The aim is to ensure the constancy of calculation, dose distribution and all outputs from the TPS. Errors can occur from 4 different parts of the whole process of treatment planning:

(1) programs,

(2) beam data,

(3) peripheral devices or

(4) operators

Regarding to QA, all these parts should be periodically tested. The periodic tests should be made by different operators of the TPS. The idea is that

operators can have their own habits in the schedule of executions and consequently use different algorithms in the program and perhaps obtain divergent results. The results could be operator dependent, hence the reason to impose standard procedure for the use of TPS.

Repeated checks are an important part of the QAP, but a continued vigilance (alertness) on the part of the operator is also required. The idea is to recognize the more subtle problems or differences which may occur. Investigation may uncover important issues which shall be resolved."

Table "2.2" showing sample of periodic tests and frequencies for TPS

Description of the testing set		
Description	Frequency	Tolerance
Printing/Plotting device	M	0.1 [cm]
Digitizer	M	0.1 [cm]
Film scanner	M	0.1 [cm]
Computer Tomography ● Geometry of particular object	M	0.1 [cm]
Computer Tomography Electronic density (rho e^-) in function of CT# ($rhoe^-$) compared to known densities relative to water (if accessible).	Y and at each revision of the CT	if $rhoe^-$ <=1.5 then 0.05 if $rhoe^-$ >1.5 then 0.1
Block cutting device	y	No diff.
Archiving and reading back of patient data	y	No diff.
MU Photons beams	m	No diff.
MU Electrons beams	m	No diff.
Standard patients/phantom with the possibility of performing checksums on beam data and executable files	y	1%
Standard patients/phantom without checksums	3m	1%
Executable and beam data files: Binary executables and beam data files.	m	No diff.

(Pierre-Alain Tercier,1999)

Unusual behavior: -

Unusual behavior can often be a warning sign of a problem that has escaped detection by routine QA. It is of vital importance that all such events, even if they seem trivial, are documented and investigated. Failure to do so can lead to major (and continuing) errors.

The major issues that relate to treatment planning errors can be summarized by four key words :

(1) Education ;

(2) Verification ;

(3) Documentation ;

(4) Communication.

Education:

Education is required both at the technical and/or professional level in terms of the use of the TPS and at the organizational level with respect to institutional policies and procedures. A very important component of education relates to understanding the software capabilities and limitations. Especially relevant are issues that relate to dose calculation normalization procedures, treatment set-up parameters as used by the computer compared with the actual treatment machine, time or MU calculations, and inhomogeneity corrections. A misinterpretation of any of these calculation procedures can potentially lead to significant treatment errors. In brachytherapy, issues of significant concern relate to source activity specification and to how the algorithm uses this specification.

Verification: -

Nearly 60% of the reported errors involved a lack of an appropriate independent secondary check of the treatment plan or dose calculation.

Documentation: -

Clear documentation is required both of each patient's individual treatment plan and of departmental policies and procedures.

Communication: -

Communication among staff members is essential for all aspects of treatment, since various people at various professional levels are involved in the treatment process. Poor communication was a key factor in a number of the errors reported.

The commissioning and QA of computerized radiation treatment planning is complex.

There is a general and dangerous tendency to use computerized outputs without an appropriate level of skepticism (suspicion) concerning their overall accuracy.

Users of TPSs need to have enough basic understanding that they can examine plans at a global level in order to decide if the plan produced and the number of MUs calculated makes common sense and is reasonable. (TRS 430)

2.2 previous study:

A study Presented at AAPM 2007, the 49th annual meeting of American Association of Physicists in Medicine, Minneapolis, USA, 22–26 July 2007 of which purpose is to report the results of commissioning and to establish a quality assurance (QA) program for commercial 3D treatment planning system (TPS) based on IAEA Technical Report Series 430. Eclipse™ v 7.3.10, (Varian Medical Systems, Palo Alto, CA, USA) TPS was commissioned for a "Clinac 6EX" (Varian Medical Systems, Palo Alto, CA, USA) linear accelerator. CT images of a phantom with various known in-homogeneities were acquired. The images were transferred to TPS and tested for various parameters related to patient data acquisition, anatomical modeling, plan evaluation and dose calculation. Dosimetric parameters including open, asymmetric and wedged shaped fields, oblique incidence, buildup region behavior and SSD dependence were evaluated.

Representative clinical cases were tested for MU calculation and point doses. The maximum variation between the measured and the known CT numbers was 20 ± 11.7 HU (1 SD). The results of all non-dosimetric tests were found within tolerance, however expansion at the sharp corners was found distorted. The accuracy of the DVH calculations depends on the grid size. TPS calculations of all the dosimetric parameters were in good agreement with the measured values, however for asymmetric open and wedged fields, few points were found out of tolerance. Smaller grid size calculation showed better agreement of dose calculation in the build-up region. Independent tests for MU calculation showed a variation within ±2% (relative to planning system), meanwhile variation of 3.0% was observed when the central axis was blocked. The test results were in agreement with the tolerance specified by IAEA TRS 430. A subset of the commissioning tests has been identified as a baseline data for an ongoing QA program.

Chapter Three

3.1- Material: -

A questionnaire form was used as a "closed interview sheet" presented to the in-charge medical physicist at the study area.

3.2- Method of study: -

3.2.1- A closed interview was conducted with the in-charge medical physicist at the study area.

3.2.2- A record review was carried out by the researcher, where NO relevant data found.

Chapter Four

4.1-Results:

The QC tests list presented to the medical physics in-charge comprises 12 test items which are taken from Swiss Society of Radiobiology and Medical Physics protocol published in recommendation “7” titled " Quality control of treatment planning system for teletherapy” by TERCIER, P.A, et al. the mentioned list has been filtered to fit the situation (there is only two cobalt"^{60}CO” units of 100 cm SAD at the area of study), so that '4' items have been deleted from the list.

Description	Frequency	Tolerance	Applicability		Performance	
			Y	N	Y	N
1-Printing/Plotting device.	m	0.1 [cm]		1		
2-Digitizer.	m	0.1 [cm]	/		2	
3-Film scanner.	m	0.1 [cm]		1		
4-Block cutting device.	y	No diff.	/		2	
5-Archiving and reading back of patient data.	y	No diff.	/		2	
6-MU Photons beams calculation of the TPS compared to previous calculation.	m	No diff.	/		2	
7-Standard patients/phantom(compare with previous	y	1%		1		

tests) with the possibility of performing checksums on beam data and executable files.						
8-Standard patients/phantom(compare with previous tests without checksums.	3m	1%		1		

m= Monthly, y= yearly, 3m= Quarterly

"1" means that the test is non-applicable due to unavailability of facility concerned.

"2" means that the test is performed in non-standard time frequency (Time change).

Chapter five

Discussion, conclusion and recommendations

5.1- Discussion:

The results of the responses indicate that:

5.1.a-Four of the eight tests are not applicable which are:

5.1.a.1- Printing/plotting device QC test is not performed temporarily because the device is out of order due to lack of supplies (Toner of the printer is not supplied).

5.1. a.2. film scanner facility is not available.

5.1-a.3.Standard patients/phantom (compare with previous tests) with the possibility of performing checksums on beam data and executable files.

Non applicable due to unavailability of test tool

5.1. a.4. Standard patients/phantom (compare with previous tests without checksums):

Non applicable due to unavailability of test tool

5.1.b. There are four of the eight QC tests that performed with time frequency **modification:**

5.1.b.1 QC test for the digitizer.

5.1. b2. QC test for Block cutting device.

5.1. b.3. QC test for archiving and reading back of patient.

5.1b.4 MU photon beams calculation of the TPS compared to previous calculation.

5.2-Conclusion:

5.2.1. There is NO standard QC protocol applied and referred to.

5.2.2- The applied QC tests are performed upon need that arises accidentally in case of observed deviations.

5.2.3- Treatment plans are verified by the work team (revision and checkup) prior to implementation.

5.3 - Recommendations:

The researcher recommends the followings:

5.3.1-To train a medical physicist in the field of QC for the TPS.

5.3.2- The assigned medical physicist shall work to design a TPS protocol taking into account the features of applicability and performance in relevance to the work requirements in regard to universal standards.

References:

1- Jamema S.V., et.al. " Commissioning and Comprehensive Quality Assurance of commercial 3D Treatment Planning System using IAEA Technical Report Series- 430"_http://link.springer.com/journal/13246 - Australasian Physics & Engineering Sciences in Medicine, September 2008, Volume 31, Issue 3, pp 207-215

2- Kutcher et al." Report of AAPM Radiation Therapy Committee Task Group 40" Medical Physics, Vol. 21, No. 4, April 1994 (pp 593-595)

3- Mijnheer, Ben et. al." Quality assurance of treatment planning systems practical examples for NON-IMRT photon beams" First edition, 2004 by ESTRO, (pp 3-4, p 83).

4- Podgorsak, F. B. et al. "Radiation oncology physics: a handbook for teachers and students" 2005, International Atomic Energy Agency, Vienna. (pp387-389, p408)

5- Pierre-Alain Tercier "Quality control of treatment planning systems for teletherapy" Recommendations No.7, Swiss Society of Radiobiology and Medical Physics, Web version 12.02.1999, Last updated :2005 (pp 21-23).

6- Technical reports series No. 430 " Commissioning and quality assurance of computerized planning systems for radiation treatment of cancer " IAEA 2004, VIENNA (pp212-219, p226, p7, p8, pp 227-228)

Appendix

Assessment of quality control procedures of treatment planning system (TPS) applied in medical physics departmentat National Cancer Institute- Madani

A questionnaire directed to quality control in-charge

*Hint /

For the test frequency Y = yearly, m = monthly, 3m= quarterly

For the responses Y = Yes, N = NO

(A) in regard to applicability under column " N ":

"1" will mean that the test is non applicable due to un availability of facility concerned.

"2" will mean that the test is not applicable due to un availability of expertise required.

(B) in regard to performance under column " Y ":

" 1 " will mean that the test is performed in the standard time frequency.

" 2 " will mean that the test is performed in non-standard time frequency. (Time change)

(C) In case of applicability "Y " matching performance " N " may you kindly justify the case; spaces will be kept under the table to state your opinion.

(it is your choice either to state your opinion or not)

Description	Frequency	Tolerance	Applicability		Performance	
			Y	N	Y	N
1-Printing/Plotting device.	m	0.1 [cm]		1		
2-Digitizer.	m	0.1 [cm]	/		2	
3-Film scanner.	m	0.1 [cm]		1		
4-Block cutting device.	y	No diff.	/		2	
5-Archiving and reading back of patient data.	y	No diff.	/		2	
6-MU Photons beams calculation of the TPS compared to previous calculation.	m	No diff.	/		2	
7-Standard patients/phantom(compare with previous tests) with the possibility of performing checksums on beam data and executable files.	y	1%		1		
8-Standard patients/phantom(compare with previous tests without checksums .	3m	1%		1		

1) Printing/Plotting device:

_____

_____

_____

2) Digitizer:

_____

_____

_____

3) Film scanner:

_____

_____

_____

4) Block cutting device :

_____

_____

_____

5) Archiving and reading back of patient data:

_____

_____

_____

6) MU Photons beams with the possibility of performing checksums on beam data and executable files:

_____

_____

_____

7) Standard patients/phantom (compare with previous tests) with the possibility of performing checksums on beam data and executable files.

_____

_____

_____

8) Standard patients/phantom (compare with previous tests without checksums).

_____

_____

_____