

**QUALITY CONTROL OF TREATMENT PLANNING SYSTEMS
FOR TELETHERAPY**

This is the first draft of a document requested by the Executive Committee of the South African Medical Physics Society.

The suggestions contained herein still need to be debated, amended where necessary and then approved by the members of the Society before this document can be added to the official library of SAMPS endorsed documents.

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1. INTRODUCTION

The treatment planning system (TPS) has become a key element in the radiotherapy process with the introduction of computer tomography (CT) based 3D conformal treatment planning.

Being a hardware and software system, each TPS may incorporate errors of different kinds, e.g.

- Software implementation errors may result in system behaviour which differs from system specifications
- Inaccuracies in algorithms and models could produce dose results not accurate enough to be used in clinical routine
- Errors could result from inaccurate or wrong model parameters supplied by the operator
- Errors could result from technical deficiencies of computer peripherals such as printers, plotters etc.
- Intentional or unintentional changes in data or software files could produce erroneous results
- Errors of different kinds could be introduced in the system during an software upgrade process

For patient safety and success of treatment, the accurate and stable functioning of the TPS is of the highest importance. This has led to the need for a comprehensive but viable set of quality assurance (QA) guidelines that can be applied in clinical treatment planning.

The South African Medical Physics Society realised the need for a document regarding QA of TPS's in South Africa. The Society however acknowledges the existence of current national TPS QA guidelines and does not wish to reinvent the wheel in this regard. Two published national documents therefor served as the basis for this national SAMPS guideline :

1) A report by the American Association of Physicists in Medicine Radiation Therapy Committee Task Group 53 "Quality Assurance for clinical radiotherapy treatment planning" ¹

2) A document by the Swiss Society of Radiobiology and Medical Physics "Quality control of treatment planning systems for teletherapy" ²

The purpose of this TPS QA recommendations are :

- to provide assistance to the medical physicist for the implementation of quality assurance procedures for a TPS for external beam therapy with photons and electrons
- to be used during evaluation and commissioning of a TPS, in case of implementation of new beam data or new software releases and also during routine clinical use
- to create an unity of doctrine in the QA of a TPS in South Africa
- to establish a base document for the public health authority

It is the Medical Physicist's responsibility to implement the QA procedures described in this document.

Building on the decision to refer to the two base documents as far as possible, the first four chapters just briefly discuss the rationale for performing the suggested tests in a specific situation. It is the responsibility of the medical physicist introducing and performing the TPS QA procedures to familiarise him-/herself with the relevant detailed explanatory text as found in the two reference publications. This compares with the situation in radiation dosimetry where SAMPS has referred its members to the AAPM TG-21 report for detailed instructions on the endorsed radiation dose calibration protocol. To assist medical physicists with the initial introduction of a TPS QA program, this document also contains a few original worksheets that may be used as examples of the type of documentation that needs to be prepared, completed, processed, act upon if necessary, and then filed for future reference purposes as part of a TPS QA program.

Chapter 1 lists QA procedure features for commissioning a TPS for both photon and electron beams, chapter 2 deals with QA aspects after a software upgrade, chapter 3 deals with the QA aspects after implementation of new beam data and chapter 4 lists QA recommendations for the routine use of a TPS. Chapter 5 lists a summary of tolerances and frequencies of suggested tests and chapter 6 contains worksheets for a representative selection of QA procedures for a TPS.

CHAPTER 1

Commissioning a Treatment Planning System

Commissioning a TPS by a qualified medical physicist is necessary before the system is used for clinical purposes. Commissioning has to validate the proper functioning of the system according to the vendor's specifications and to clinical requirements. The results can be used to establish standards of acceptance for demonstration of the correct working of the TPS in regular QA-checks. Calculations for commissioning test cases shall be compared against measurements done at the same time as those used to characterise the treatment unit.

Table 1: Acceptance test features (from table 2-2 in the TG-53 report)

Topic	Tests
CT input	Create an anatomical description on a standard set of CT scans provided by the vendor, in the format which will be employed by the user.
Anatomical description	Create a patient model based on the CT data discussed above. Contour the external surface, internal anatomy, etc. Create 3-D objects and display.
Beam description	Verify all beam technique functions work, using a standard beam description provided by the vendor
Photon beam dose calculations	Perform dose calculations for a standard photon beam dataset. Tests should include various open fields, different SSD's, blocked fields, MLC-shaped fields (if applicable), inhomogeneity test cases, multi-beam plans, asymmetric jaw fields, wedged fields, and other applicable tests.
Electron beam dose calculations	Perform a set of dose calculations for a standard electron beam dataset. Include open fields, different SSD's, shaped fields, inhomogeneity test cases, surface irregularity test cases, and other applicable tests.
Dose display, dose volume histograms	Display dose calculation results. Use a standard dose distribution provided by the vendor to verify that the DVH code works as described. User-created dose distributions may also be used for additional tests.
Hardcopy output	Print out all hardcopy documentation for a given series of plans, and confirm that all textual and graphical information is output correctly

CHAPTER 2

Tests after implementation of a new software release

After any software upgrade (installation of new releases or other modification), it is recommended to check the reliability, correctness and constancy of relevant parameters and of the calculation algorithm. To be more efficient, a detailed study of the changes expected in the new version, and good documentation of all expected changes shall be furnished by the vendor. New software releases and upgrades could be classified into two subsets: those not directly influencing calculation algorithms and those where substantial variation on physical models implemented are introduced (e.g. change in irregular fields treatment, head scatter corrections etc).

In the latter case, given the complexity of TPS program structures, the whole calculation algorithm has to be considered changed and as a consequence all involved treatment units shall be checked as already discussed for commissioning.

In the case of software releases related only to ancillary or to presentation utilities (like graphic tools added or modified), only a subset of the commissioning procedure checks are mandatory before the use of the TPS in clinical routine.

Table 2: Acceptance tests for a new software release not affecting physical algorithms (from par. 2.2 in the SSRMP report)

Topic	Test
Non dosimetric tests	All clinically used tools and programs, whether or not involved in the software upgrade, shall be checked: coarse checks, geometry and 3D functionality, peripherals need a control as for the commissioning. It is also important to check for the completeness of the functions, as this may interfere with clinical routine.
Dosimetric tests <ul style="list-style-type: none"> • Photon beams • Electron beams 	<ul style="list-style-type: none"> • Point dose at 3 depths (d_{max}, 5cm, 10cm) for a $5 \times 5 \text{cm}^2$, $10 \times 10 \text{cm}^2$ and maximum open square fields, a rectangular $5 \times 30 \text{cm}^2$ field and an irregular field. Profiles : for open beams ($10 \times 10 \text{cm}^2$ and the maximum square field) at 10cm depth; for wedged beams only the maximum field allowed at 10cm depth • Point dose for reference field, at 2 depths: d_{max} and a point in the fall off region Profiles in the same conditions
Standard cases	Isodoses, monitor unit calculations and DVH results

	from the new release, compared with those obtained from the previous one shall match without any quantitative difference unless mentioned as corrections by the vendor.
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CHAPTER 3

Tests after addition of a new therapy unit and/or implementation of new beam data

The implementation of a new therapy unit or new beam data concerns all steps of a TPS quality assurance program; this implies that in order to exclude any systematic error in treatment planning, all the functions relied to this new treatment unit have to be carefully checked and evaluated before clinical use. From this statement, it follows that a complete set of tests of the software and dose calculation is required as for commissioning.

CHAPTER 4

Routine TPS checks

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 shall be periodically tested. The periodic tests shall 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.

Repeated checks as formulated here are an important part of the quality assurance program, but a continual vigilance on the part of the operator is also required.

In vivo dosimetry is an overall test of the TPS and should be performed on all new patients as stipulated in the latest licensing conditions issued by the Department of Health.

Table 3: Routine treatment planning system checks (from par.4.2 in the SSRMP document)

Topic	Test
Peripherals	Compare the testing results of printing and plotting devices, digitiser, film scanner, computer tomography system, block cutting device, archiving and retrieving of patient data with previous results.
Monitor units	Compare the MU's of photon and electron beams with previous results
Standard treatment plans	Test all output of standard treatment plans with previous results.
Checksum	The TPS program code and data cannot be modified by the operator, therefor it should be verified that it has not been corrupted by any virus or wrong operations. If a virus corrupts programs or somebody makes a wrong operation on the system (e.g. causing a change in one or more treatment unit data files), a checksum utility (which shall be supplied by the vendor) pointing on the executables, beam data and other important files can identify the problem. A good idea is to execute the checksum utility at each start of the TPS by including it in the boot procedure.

CHAPTER 5

Summary of all tests that should be performed as part of a TPS QA program

Table 4: Suggested QA procedures with associated tolerances and frequencies
(based mainly on the appendix in the SSRMP document as well as table 5-1 in the AAPM TG53 report)

Description	Tolerance	Frequency
Peripheral devices <ul style="list-style-type: none"> • Printing/plotting device • Digitiser • Film scanner • CT - shape of any particular object • CT - electron density compared to known densities in water • Archiving and retrieving of patient data • Block cutting device 	1 mm 1 mm 1 mm 1 mm 10% no diff. no diff.	Monthly Monthly Monthly Monthly Monthly Annually Annually
Photon beam dosimetry <ul style="list-style-type: none"> • Monitor unit calculation • Standard treatment plan outputs • Point dose calculations and factors (PDD, TMR etc for open and irregular fields) • Beam profiles (including open, wedged and asymmetric beams) • Inverse square law correction • Wedge and transmission factors 	1% 1% 2% 2% 2% 2%	Monthly 3 Monthly Annually Annually Annually Annually
Electron beam dosimetry <ul style="list-style-type: none"> • Monitor unit calculation • Standard treatment plan outputs • Point dose calculations and factors (PDD for open and irregular fields) • Beam profiles • Inverse square law correction • Beam size 	1% 1% 2% 2% 2% 2 mm	Monthly 3 Monthly Annually Annually Annually Annually
Checksum of program files	No diff.	Weekly

CHAPTER 6

Example worksheets for TPS QA purposes

1. Peripheral devices

1.1 CT Interface

1.1.1 Correct implementation of CT scanner in software

1.1.1.1 Check the name of the CT interface installed in the treatment planning software :

CT Interface : _____

1.1.1.2 Check the type or model of the installed CT scanner :

CT Type/Model : _____

1.1.1.3 Check that all menu items are working correctly :

YES or NO

1.1.2 Correct display of different types of CT images

1.1.2.1 Check that all images read with the CT interface are displayed correctly on the screen. Check both transversal and scout view images

YES or NO

1.1.2.2 Check that all scout view images are labelled correctly

YES or NO

1.1.2.3 Check that all image orientations are correct after reading the images to the treatment planning system

YES or NO

1.1.3.1 Correct conversion of Hounsfield numbers to electron density values

Material / Ref.CT-value	CT-value (TPS)	Ref. e ⁻ density	TPS e ⁻ dens
Ln300 Lung / -561		0.438	
CT Solid water / -8.2		1.000	
LV 1 Liver / 68.9		1.050	
CB2-30% CaCO ₃ / 458.2		1.285	
SB3 Cortical Bone/ 1273.2		1.707	

1.1.3.2 Hounsfield versus electron density is correct :

YES or NO

1.1.4 Correct transfer of pixel size

1.1.4.1 Measure at least four distances on X-ray film or at the CT unit and compare with distances measured between identical points inside the treatment planning system :

Axis (X/Y)	Distance measured outside TPS	Distance measured in TPS
X		
X		
Y		
Y		

1.1.4.2 Pixel size is correct :

YES or NO

1.2 Digitizer

1.2.1 Accurate transfer of geometric figures

Digitize at least three (3) geometric figures (e.g. circle, square, triangle)

1.2.1.1 Measure and compare the following dimensions on paper and with calipers within the TPS :

	Circle		Square		Triangle	
Dimension	Orig	TPS	Orig	TPS	Orig	TPS
D ₁						
D ₂						
D ₃						

1.2.1.2 Dimensions correct : YES or NO

1.3 Plotter

1.3.1 Accurate transfer of geometric figures

Plot at least three (3) geometric figures (e.g. circle, square, triangle)

1.3.1.1 Measure and compare the following dimensions on the TPS screen and the paper plot :

	Circle		Square		Triangle	
Dimension	TPS	Plot	TPS	Plot	TPS	Plot
D ₁						
D ₂						
D ₃						

1.3.1.2 Dimensions correct : YES or NO

1.4 Block/compensator cutting device

1.4.1 Cutting precision correct YES or NO

1.4.2 Block filter – center position correct YES or NO

1.4.3 System precision correct YES or NO

1.4.4 Compensator filter cut correct YES or NO

Implementation of peripheral devices correct : Yes or NO

SIGNATURE : _____

DATE : _____

2 Treatment planning software : Configuration and algorithms

2.1 Photon beam point dose calculations

5 x 20 field on square water phantom. Calculation matrix = 0.5cm Obtain %DD utilising a profile measurement along beam central axis.

Treatment unit 1 : _____

Energy	D _{max}	D ₅₀	0.5cm	10 cm	20cm

Treatment unit 2 : _____

Energy	D _{max}	D ₅₀	0.5cm	10 cm	20cm

Treatment unit 3 : _____

Energy	D _{max}	D ₅₀	0.5cm	10 cm	20cm

Treatment unit 4 : _____

Energy	D _{max}	D ₅₀	0.5cm	10 cm	20cm

Photon beam point dose calculation correct : YES or NO

2.2 Electron beam point dose calculations

10 x 10 field on square water phantom. Calculation matrix = 0.5cm Obtain %DD utilising a profile measurement along beam central axis.

Treatment unit 1 : _____

Energy	D _{max}	D ₉₀	D ₈₅	D ₈₀	D ₅₀

Treatment unit 2 : _____

Energy	D _{max}	D ₉₀	D ₈₅	D ₈₀	D ₅₀

Electron beam point dose calculation correct : YES or NO

2.3 Photon beam dose distributions and MU checks

2.3.1 Open fields

Plan a 10 x 10 field on a square water phantom. Calculation matrix = 0.5cm. No normalization. Plot the resulting dose distribution for each photon beam energy. Calculate the MUs required to deliver 2 Gy at d_{max} .

2.3.2 Wedged fields

Plan a 10 x 10 field on a square water phantom. Calculation matrix = 0.5cm. No normalization. Use a 45° physical wedge or a 50% motorised/dynamic wedge in the field. Plot the resulting dose distribution for each photon beam energy. Calculate the MUs required to deliver 2 Gy at d_{max} .

2.3.3 Asymmetric fields

Plan a 5:5 x 0:10 field on a square water phantom. Calculation matrix = 0.5cm. No normalization. Plot the resulting dose distribution for each photon beam energy. Calculate the MUs required to deliver 2 Gy at d_{max} .

2.3.4 Parallel opposed fields

Plan two parallel opposed 15x5 fields on a square water phantom. Calculation matrix = 0.5cm. No normalization. Plot the resulting dose distribution for each photon beam energy. Calculate the MUs required to deliver 2 Gy at the midplane.

Treatment unit 1 : _____

Energy	Type of field	Dose distr. Plot	MU for 2 Gy
1)	Open	Y / N	(d_{max})
	Wedged	Y / N	(d_{max})
	Asymmetric	Y / N	(d_{max})
	Parallel opposed	Y / N	(midplane)

2)	Open	Y / N	(d _{max})
	Wedged	Y / N	(d _{max})
	Asymmetric	Y / N	(d _{max})
	Parallel opposed	Y / N	(midplane)

Treatment unit 2 : _____

Energy	Type of field	Dose distr. Plot	MU for 2 Gy
1)	Open	Y / N	(d _{max})
	Wedged	Y / N	(d _{max})
	Asymmetric	Y / N	(d _{max})
	Parallel opposed	Y / N	(midplane)
2)	Open	Y / N	(d _{max})
	Wedged	Y / N	(d _{max})
	Asymmetric	Y / N	(d _{max})
	Parallel opposed	Y / N	(midplane)

Treatment unit 3 : _____

Energy	Type of field	Dose distr. Plot	MU for 2 Gy
1)	Open	Y / N	(d _{max})
	Wedged	Y / N	(d _{max})
	Asymmetric	Y / N	(d _{max})
	Parallel opposed	Y / N	(midplane)
2)	Open	Y / N	(d _{max})
	Wedged	Y / N	(d _{max})
	Asymmetric	Y / N	(d _{max})
	Parallel opposed	Y / N	(midplane)

Treatment unit 4: _____

Energy	Type of field	Dose distr. Plot	MU for 2 Gy
1)	Open	Y / N	(d _{max})
	Wedged	Y / N	(d _{max})
	Asymmetric	Y / N	(d _{max})

	Parallel opposed	Y / N	(midplane)
2)	Open	Y / N	(d _{max})
	Wedged	Y / N	(d _{max})
	Asymmetric	Y / N	(d _{max})
	Parallel opposed	Y / N	(midplane)

Photon beam MU calculation correct : YES or NO

Photon beam dose distributions identical to previous results: YES or NO

2.4 Electron beam dose distributions and MU checks

2.4.1 Open fields

Plan a 9 x 5 field on a square water phantom. Calculation matrix = 0.5cm. No normalization. Plot the resulting dose distribution for each electron beam energy. Calculate the MUs required to deliver 2 Gy at the 90% isodose level.

2.4.2 Irregular electron cutout field

Plan a 10 x 10 field on a square water phantom. Insert an irregular cutout that will give a triangular field with a base and height of 10cm. Calculation matrix = 0.5cm. No normalization. Plot the resulting dose distribution for each electron beam energy. Calculate the MUs required to deliver 2 Gy at the 90% isodose level.

2.4.3 Circular electron cutout field

Plan a 10 x 10 field on a square water phantom. Insert a circular cutout with a diameter of 5cm. Calculation matrix = 0.5cm. No normalization. Plot the resulting dose distribution for each electron beam energy. Calculate the MUs required to deliver 2 Gy at the 90% isodose level.

Treatment unit : _____

Energy	Type of field	Dose distr. Plot	MU for 2 Gy at 90%
1)	Open	Y / N	
	Irregular cutout	Y / N	
	Circular cutout	Y / N	
2)	Open	Y / N	
	Irregular cutout	Y / N	
	Circular cutout	Y / N	
3)	Open	Y / N	
	Irregular cutout	Y / N	
	Circular cutout	Y / N	
4)	Open	Y / N	
	Irregular cutout	Y / N	
	Circular cutout	Y / N	
5)	Open	Y / N	
	Irregular cutout	Y / N	
	Circular cutout	Y / N	
6)	Open	Y / N	
	Irregular cutout	Y / N	
	Circular cutout	Y / N	

Electron beam MU calculation correct : YES or NO

Electron dose distributions are identical when compared to previous results :
YES or NO

Configuration and calculation algorithms of the external beam treatment planning software give identical results for an identical test set of treatment plans previously calculated with this TPS software : YES or NO

SIGNATURE : _____

DATE : _____

3 External beam treatment planning software : Standard patient treatment files

Plan at least five (5) patients that are representative of the different types of cancer patients being treated in the hospital. Use a calculation grid of 0.5 cm and normalize the treatment plan according to the ICRU specifications. Calculate the coronal and sagittal views in the plane that passes through the isocentre. Determine the MU required per field to deliver 2 Gy per fraction to the 100% isodose volume. Calculate DVH's for each of the areas of interest in the treatment volume.

3.1 Dose distribution check

Compared to previous results obtained with this treatment planning software,

3.1.1 The dose distributions on the axial view through the isocentre are identical :

YES or NO

3.1.2 The dose distributions on the coronal view through the isocentre are identical :

YES or NO

3.1.3 The dose distributions on the sagittal view through the isocentre are identical :

YES or NO

3.2 Shielding block transmission factor check

Compared to previous results obtained with this treatment planning software,

3.2.1 The printed shielding block transmission factors are identical :

YES or NO

3.3 Tray transmission factor check

Compared to previous results obtained with this treatment planning software,

3.3.1 The printed tray transmission factors are identical :

YES or NO

3.4 Wedge transmission factor check

Compared to previous results obtained with this treatment planning software,

3.4.1 The printed wedge transmission factors are identical :

YES or NO

3.5 Entrance dose check

Compared to previous results obtained with this treatment planning software,

3.5.1 The printed entrance dose for all fields are identical :

YES or NO

3.6 Equivalent field size check

Compared to previous results obtained with this treatment planning software,

3.6.1 The printed equivalent field sizes are identical :

YES or NO

3.7 Calculated monitor unit check

Compared to previous results obtained with this treatment planning software,

3.7.1 The printed MUs for each field are identical :

YES or NO

3.8 Dose-Volume histogram check

Compared to previous results obtained with this treatment planning software,

- 3.8.1 The DVH plots are identical : YES or NO
- 3.8.2 The calculated maximum doses are identical : YES or NO
- 3.8.3 The calculated mean doses are identical: YES or NO
- 3.8.4 The calculated median doses are identical : YES or NO
- 3.8.5 The calculated minimum doses are identical : YES or NO

An identical set of patient input data gives identical dosimetry results when compared to previous results obtained with this external beam treatment planning software : YES or NO

SIGNATURE : _____

DATE : _____

THE EXTERNAL BEAM TREATMENT PLANNING SOFTWARE IS APPROVED FOR CONTINUING CLINICAL USE :

YES or NO

SIGNATURE : _____

DATE : _____

REFERENCES

- 1) "Quality assurance for clinical radiotherapy treatment planning", AAPM Radiation Therapy Committee Task Group Report 53, Med. Phys. 25(10), Oct 1998
- 2) "Quality control of treatment planning systems for teletherapy", Swiss Society of Radiobiology and Medical Physics, ISBN 3-908125-23-5, also available at www.sgsmp.ch/r07tps-e.htm, Feb 1999
- 3) "Commissioning and quality assurance of treatment planning systems", J. Van Dyk et al, Int.J.Rad.Oncol.Biol.Phys, vol 26, p261-271