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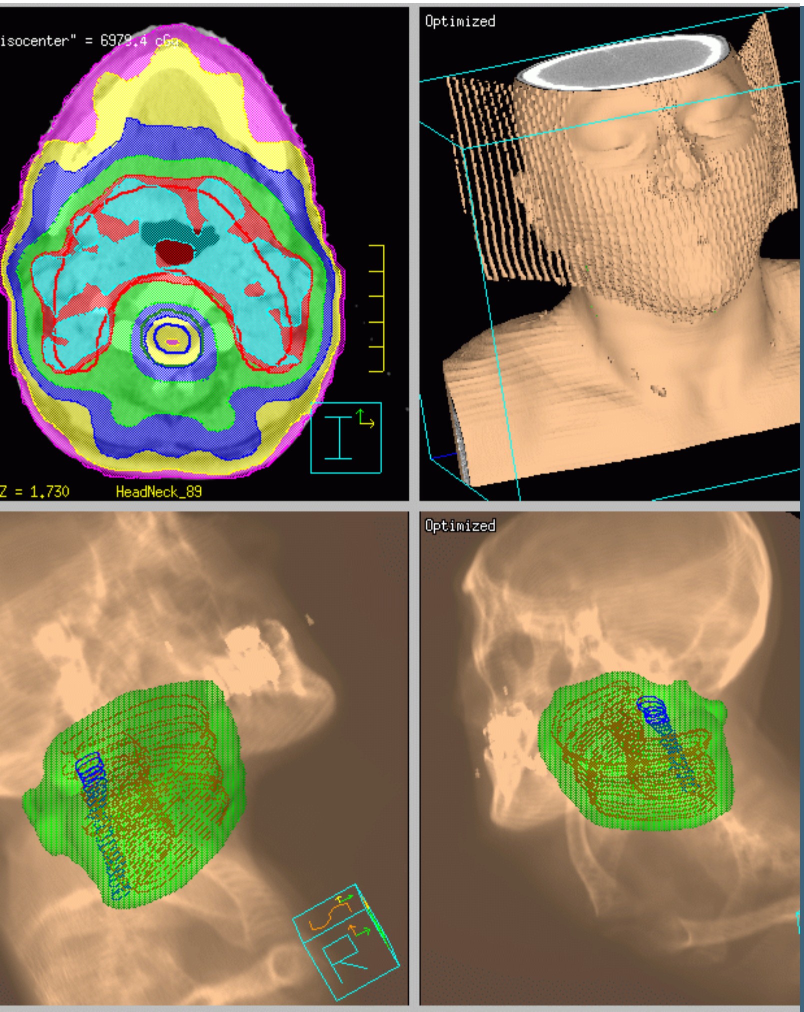

RC 122: Acceptance Testing and QA of Treatment Planning Systems

Jacob (Jake) Van Dyk
London Regional Cancer Program
University of Western Ontario
Geoffrey S. Ibbott
MD Anderson Cancer Center
Radiological Physics Center
University of Texas

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Excellence through Quality Assurance

Learning Objectives

1. To demonstrate the importance of the quality assurance (QA) of radiation treatment planning systems (RTPS) by reviewing significant treatment errors associated with their use.
2. To review the major functionality of a modern RTPS.
3. To highlight and summarize various reports that have made recommendations regarding acceptance, commissioning and QA of RTPSs with special emphasis on IEC-62083 and IAEA TRS-430.
4. To discuss accuracy requirements and criteria of acceptability of the modern RTPS.
5. To summarize acceptance testing procedures as proposed by the IAEA for a modern RTPS.
6. To provide an overview of commissioning a modern RTPS.
7. To provide an overview of the quality control associated with a modern RTPS.

Disclosures

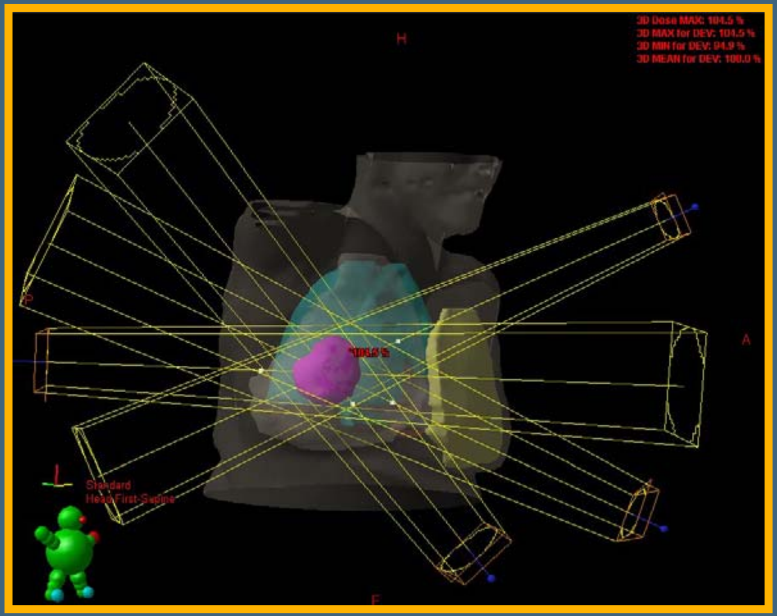
- J. Van Dyk
  - License agreement, Modus Medical Devices Inc, London, ON, Canada
- G. Ibbott
  - Consultant, IsoRay Inc, Richland, WA
  - Consultant, Varian Associates, Palo Alto, CA
  - Spouse, Employee, Accuray Incorporated, Sunnyvale, CA

Overview

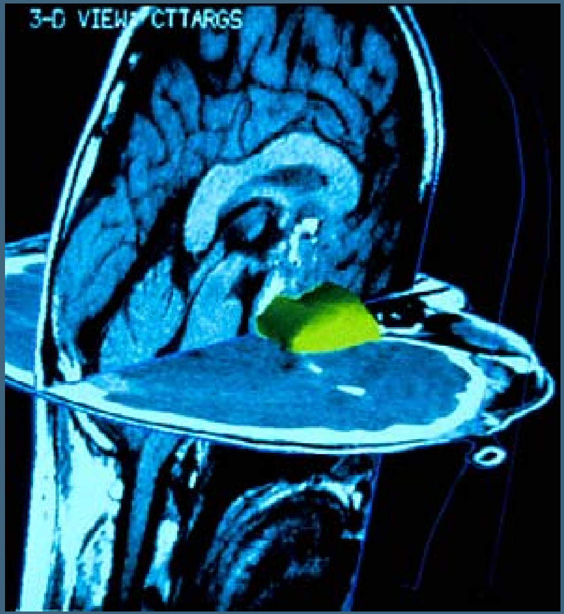
- Scope of problem
- Complexity of modern RTPS
- Recent reports & recommendations
- Accuracy & criteria of acceptability
- IAEA proposal for acceptance testing
- IAEA report on commissioning
- Issues not addressed in current reports

Introduction

- Technological revolution in radiation oncology
  - Enhanced use of imaging
  - Computer-controlled dose delivery
  - Tighter margins
  - Higher doses
  - Dynamic delivery
  - Smaller beams
- Central to this is the radiation treatment planning system (RTPS)



Introduction



IAEA TRS-430

- Modern RTPS
  - Increased use of patient images
    - Possibly from various imaging modalities
  - Enhanced 3-D displays
  - More sophisticated dose calculation algorithms
  - More complex treatment plan evaluation tools
  - Generation of images used for treatment verification
  - Dynamic delivery
    - Wedges
    - IMRT

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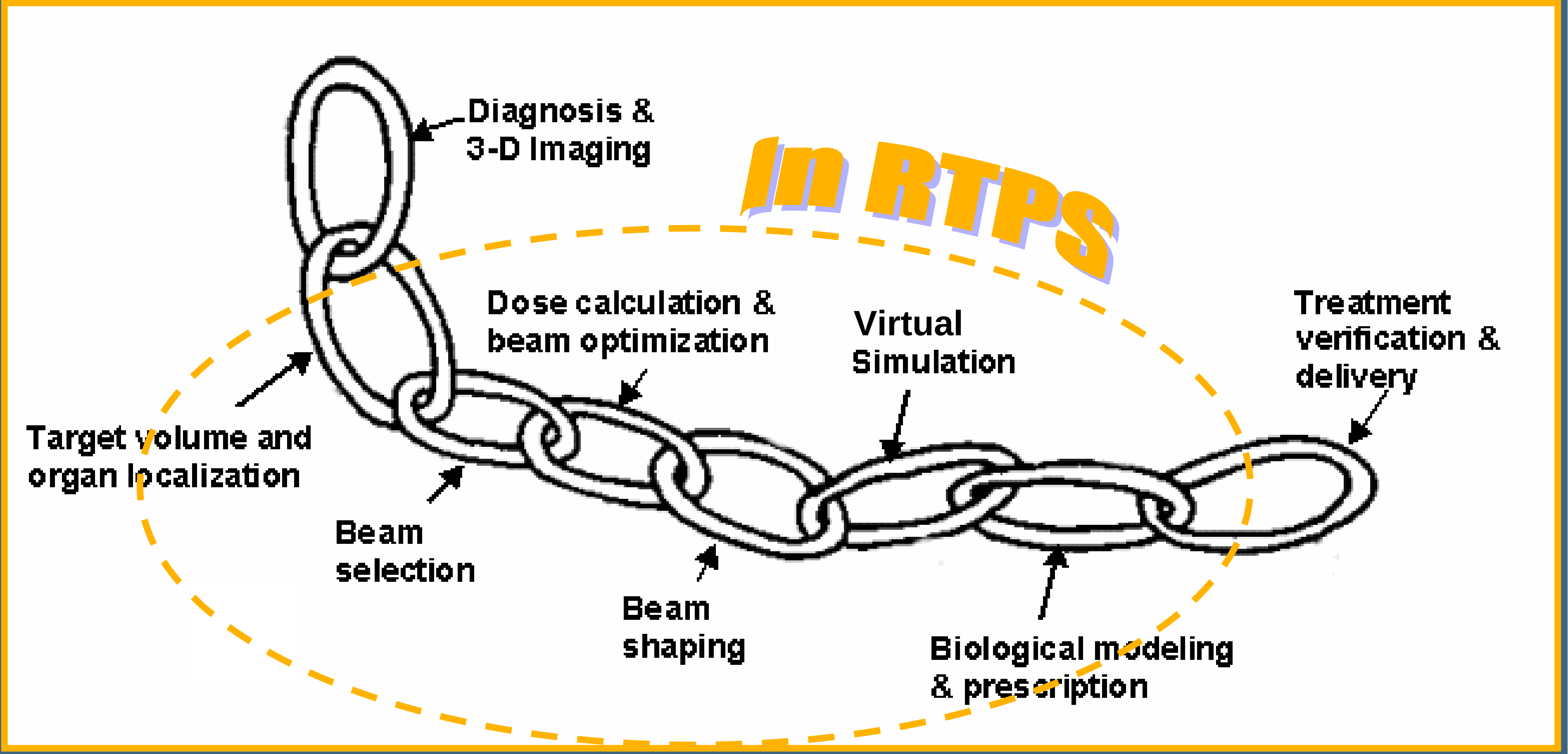
Radiation Therapy Process



Adapted from S Webb

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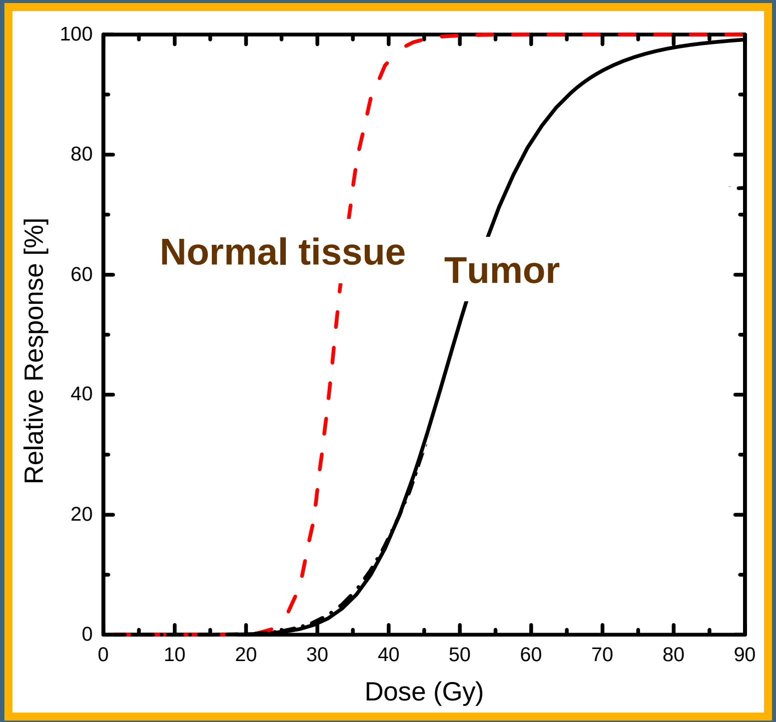
QA in Radiation Therapy (RT)

- Two considerations in radiation therapy

Need for accuracy in RT process



Avoidance of treatment errors

2008-11-30
RC-122 RSNA

Need for Accuracy in Dose Calculations

- General accuracy desired in dose delivered to patient: **5%**

	Uncertainty Type	*Uncertainty Range (%)*
A	Absorbed dose to reference point in water phantom	2.5
B	Determination of relative dose (Measurement away from reference point)	2.5
C	Relative dose calculations	2.5
D	Patient irradiation	2.5
E	**Overall**	**5.0**

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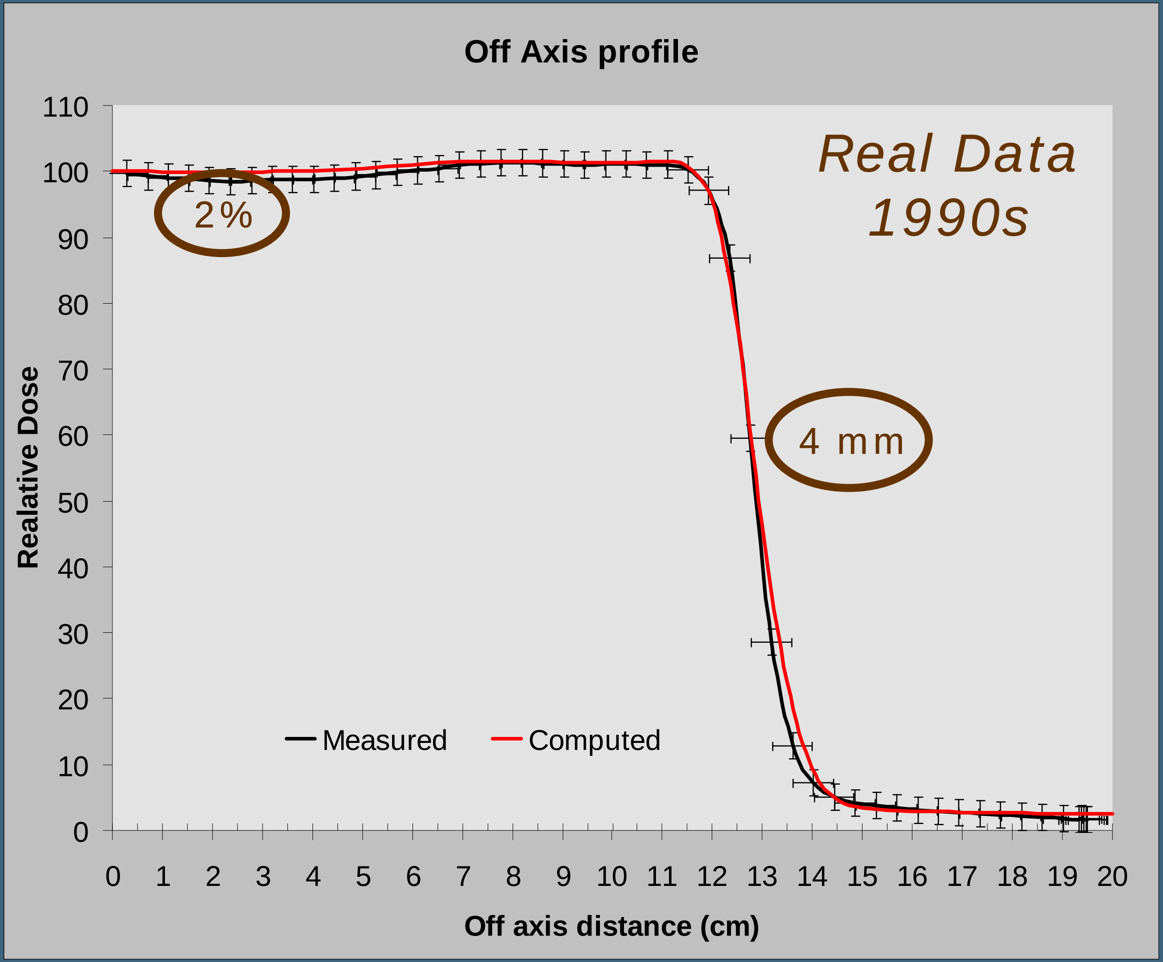
ICRU Goal in Dose Calculation and Spatial Accuracy

- *ICRU 42, 1987 Recommends*
- Relative dose accuracy in uniform dose region: **2%**
- Spatial accuracy in high dose gradient: **2 mm**



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Avoidance of Treatment Errors

- Error
  - "The failure of planned action to be completed as intended (i.e., error of execution) or the use of a wrong plan to achieve an aim (i.e., error of planning)."

Institute of Medicine. To Err is Human: Building a Safer Health System, 2000.

Euphemisms for “Errors”

- Accidents
- Incidents
- Events
- Mistakes
- Misadministrations
- Unusual occurrences
- Discrepancies
- Adverse events

Medical Errors - General

- In United States…
- Annual errors
  - 44K-98K people die from medical errors
  - More than motor vehicle accidents, breast cancer or AIDS
  - Total annual cost $37.6 to $50 billion
- Most common types
  - Technical (44%)
  - Diagnosis (17%)
  - Failure to prevent injury (12%)
  - Use of drugs (10%)

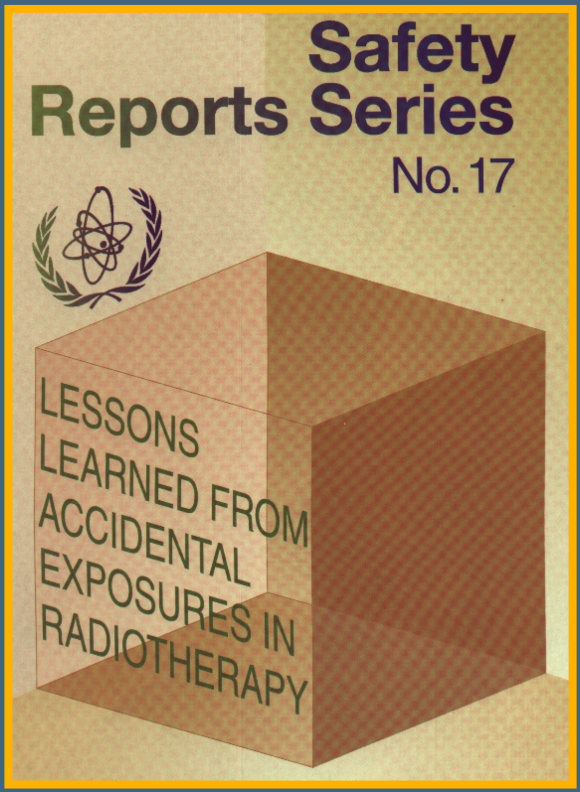
Institute of Medicine. To Err is Human: Building a Safer Health System, 2000.

Medical Error Analysis

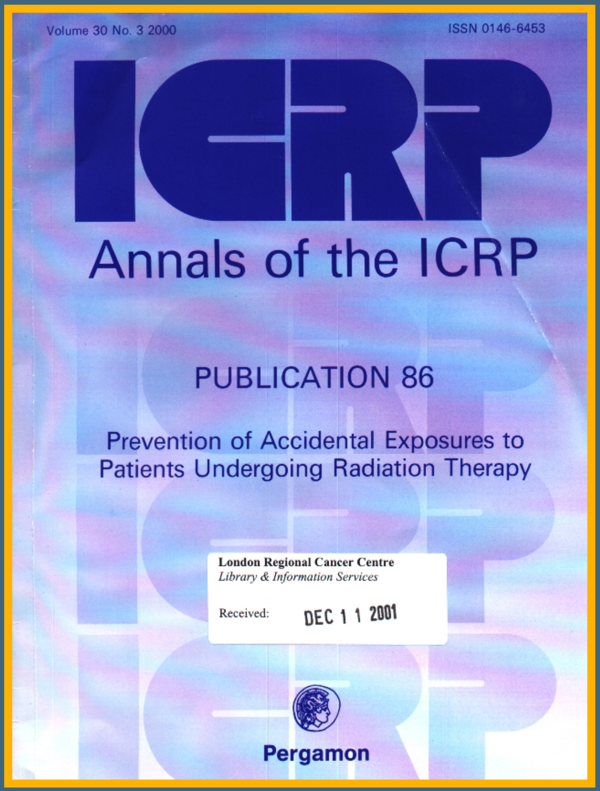
Recently, more public & acceptable practice

- Sample references - medicine in general
  - *Institute of Medicine. To Err is Human: Building a Safer Health System, 2000.*
  - *Sokol & Molzen. The Changing Standard of Care in Medicine, J Legal Med, 2002.*
  - *Baker et al. The Canadian Adverse Events Study: the incidence of adverse events among hospital patients in Canada. CMAJ 2004.*
- Sample references - RT
  - *Macklis et al. Error Rates in Clinical Radiotherapy. J Clin Oncol, 1998.*
  - *Cosset. ESTRO Breur Gold Medal Award Lecture 2001. Irradiation Accidents - Lessons for Oncology? Radioth Oncol, 2002*

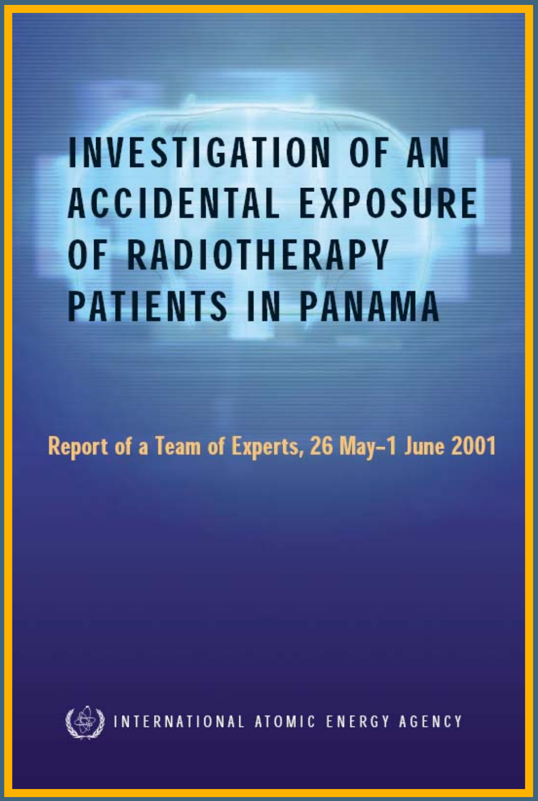
Avoidance of Errors in RT



IAEA 2000

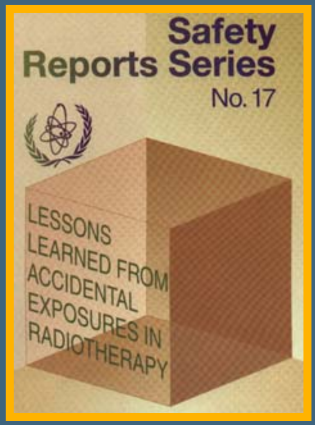


ICRP 2000



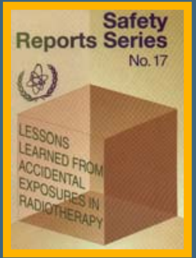
IAEA 2001

IAEA: Lessons Learned from Accidental...



- Describes 92 accidental exposures
  - 26 relate to radiation treatment planning
    - 16 external beam therapy
    - 10 brachytherapy

IAEA: Categories of Errors



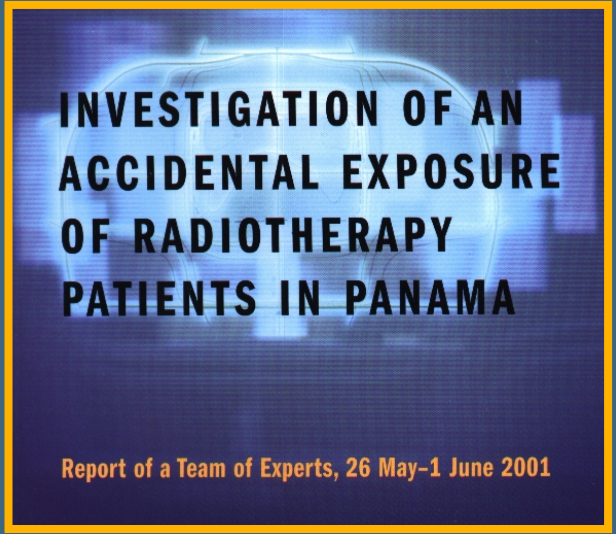
Categories	*Number of errors*
Radiation measurement systems	5
External beam:	
Machine commissioning & calibration	15
External beam therapy:	
Treatment planning, patient setup and treatment	26
Decommissioning of teletherapy equipment	2
Mechanical and electrical malfunctions	4
Brachytherapy:	
Low dose rate sources and applicators	29
Brachytherapy: High dose rate	3
Unsealed sources	8
	92

IAEA: Lessons… Examples

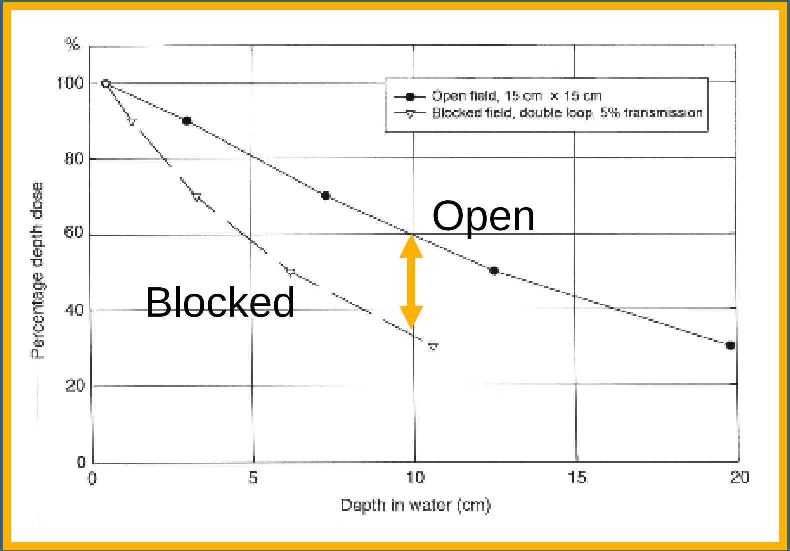
Description	***Comments***
Inconsistent/incorrect data set	Lack of proper commissioning/verification
Insufficient understanding of algorithm	Lack of understanding on use of wedge factors
Incorrect calculation of treatment times	Lack of independent check
Incorrect distance correction	Lack of understanding/training Lack of independent check
Misunderstanding of complex treatment plan - verbal communication	Lack clear documentation Ineffective communication
Incorrect positioning of beams on patient	Poor implementation of instructions
Wrong source strength	Insufficient training/understanding No independent check
Wrong isotope	No independent check
Error in removal time	No independent check

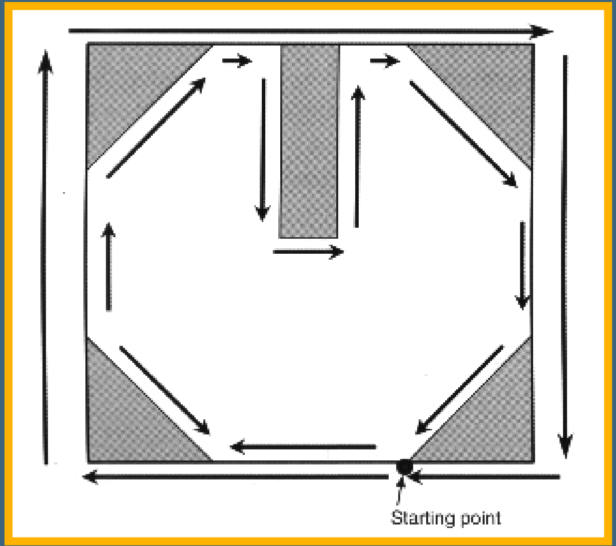
Panama Incident

IAEA



- Error due to digitizer entry of shielding blocks
- Dose error up to ~2 times
- Affected 28 patients
  - 17 died, 13 rectal complications





Factors Contributing to Errors

- Inadequate instructions in the RTPS manual
- Insufficient QA in treatment planning process
  - No manual checks
  - No written procedure of changes when entering the blocks
- Work organization
- Excessive workload
- Lack of coordination between members of radiation therapy team

Errors Related to ***Modern Technology***

- Sample errors
  - 2004-2005. Epinal, France. 23 patients overdosed by 7-34%. Error in interpretation of dynamic vs physical wedge
  - 2006. Glasgow, Scotland. Error associated with a change in process due to update of a record and verify system (Varis 7). ~60% overdose to brain. Patient died.
  - 2007. Toulouse, France: stereotactic radiosurgery equipment miscalibration, 145 patients over-exposed
  - 2007. Detroit, MI. Gamma Knife
    - Reported 29 Oct 2007. Wrong side of brain treated – coordinates were reversed – related to how patient was scanned with MRI – feet first vs head first.
  - RPC IMRT phantom data
    - Later…

Errors in RT: Contributing Factors

- Insufficient education
- Lack of procedures/protocols as part of comprehensive QA program
- Lack of supervision of compliance with QA program
- Lack of training for “unusual” situations
- Lack of a “safety culture”

Complexity of Modern RTPS

- Many issues to address
  - Hardware
  - Software
    - Use of images, 3-D, IMRT, optimization, plan evaluation
  - Networking
    - Dosimetry devices
    - Imaging devices
    - Treatment machines
    - Oncology information system
    - Physicians'/physicists' offices/homes
- Some capabilities not easy to test

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Components of 3-D RTPS

Hardware

- CPU
- High resolution graphics
- Mass storage (hard disc)
- Floppy disk/CD ROM
- Keyboard & mouse
- High resolution monitor
- Digitizer
- Laser/color printer
- Backup storage facility
- Network connections

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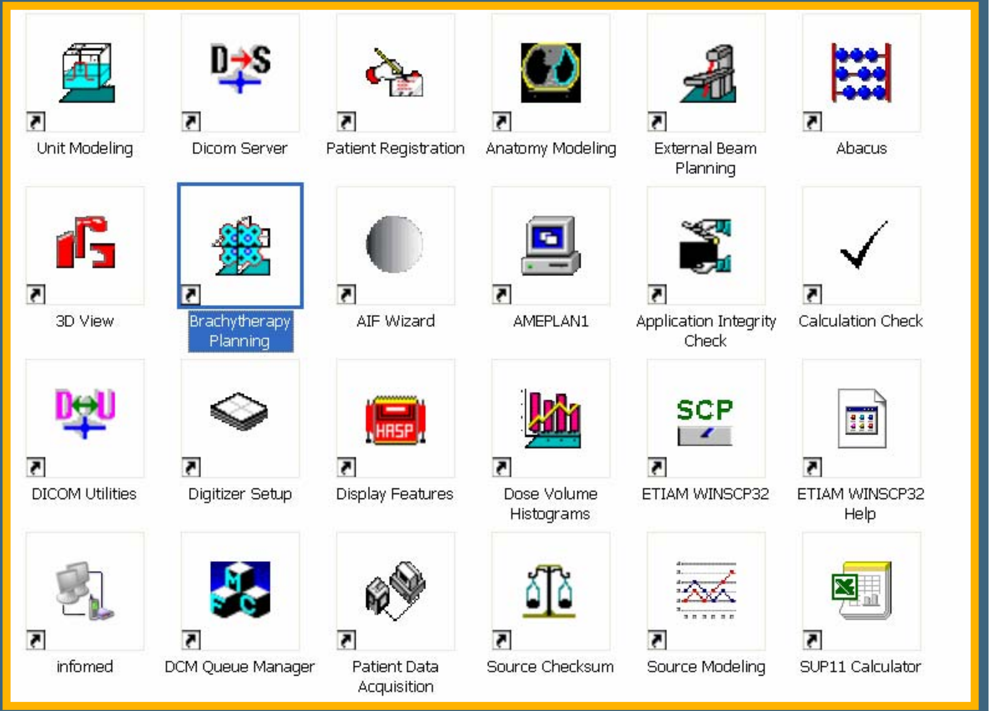
Components of 3-D RTPS

Software

- Input routines
- Anatomy modeling
- Beam geometry (virtual simulation)
- Dose calculations
- Dose volume histograms/evaluation tools
- Digitally reconstructed radiographs
- Output [hardcopies, network, web connection (RTOG)]



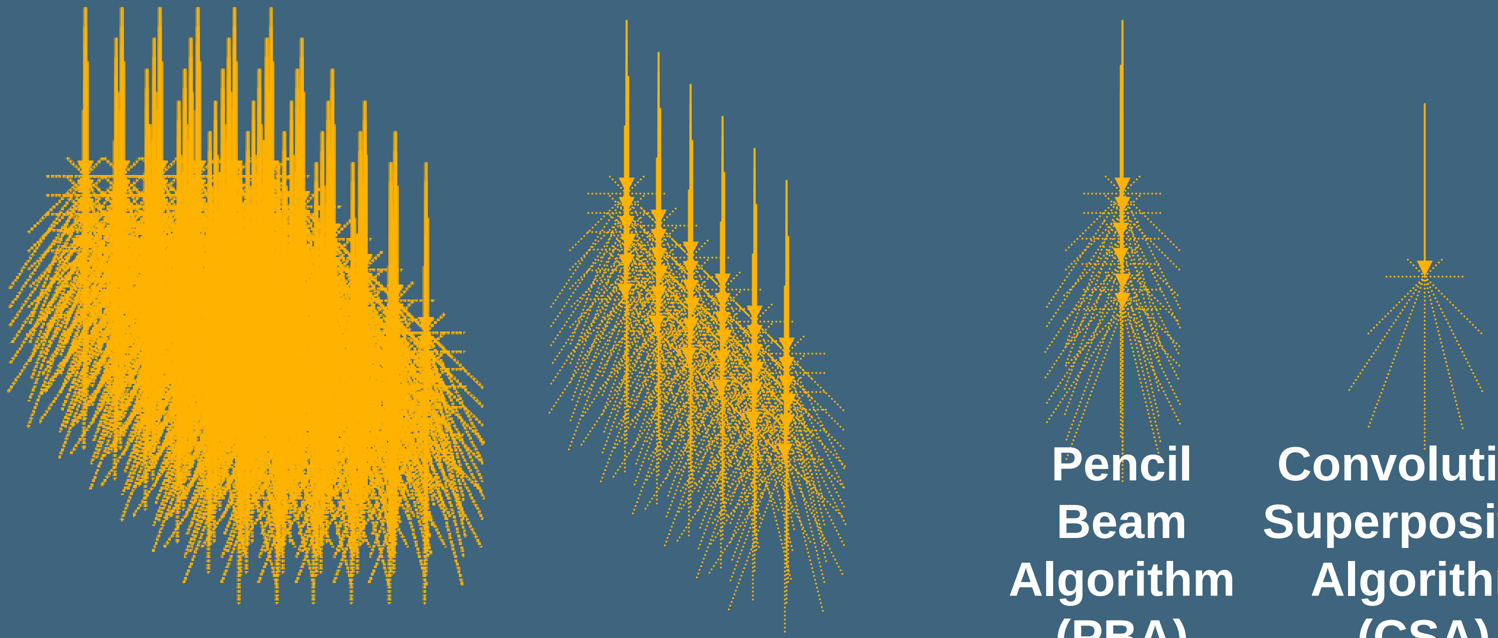
TPP Nucletron

Dose Calculation Algorithms

A. Scatter Integration

Superposition Principle

Beam Kernel | Slab Kernel | Pencil Kernel | Point Kernel



Pencil Beam Algorithm (PBA)

Convolution/ Superposition Algorithm (CSA)

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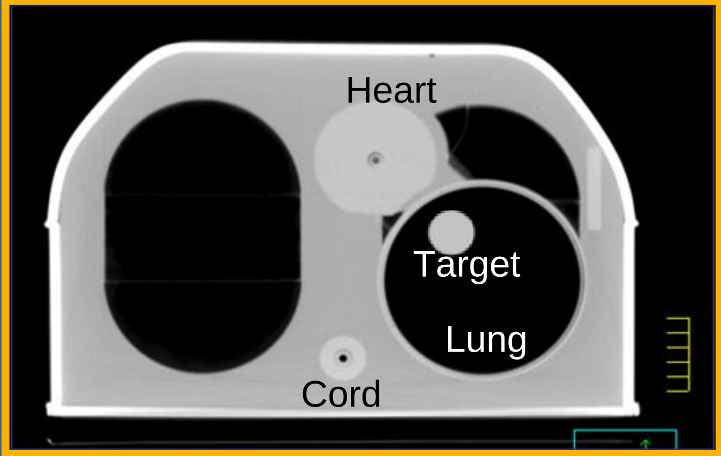
IMRT Heterogeneity Corrections

TPS	IMRT QA correction multiplier	Ratio of TPS calculation (corrected) to TLD measurement		
		Tumor	Heart	Cord
Pinnacle (CSA)	1.027	0.992	1.021	0.964
Corvus (PBA)	1.055	1.050	1.093	1.090
Eclipse AAA (CSA)	1.007	1.036	1.112	1.099
Eclipse (PBA)	0.993	1.049	1.065	1.042
TornoTherapy (CSA)	0.994	1.021	0.974	0.851



- Convolution/Superposition Algorithm (CSA)
  - Average = 1.01 ± 0.08
  - ±5%/3 mm : 85% pixels
- Pencil Beam Algorithm (PBA)
  - Average = 1.07 ± 0.02
  - ±5%/3 mm : 50% pixels

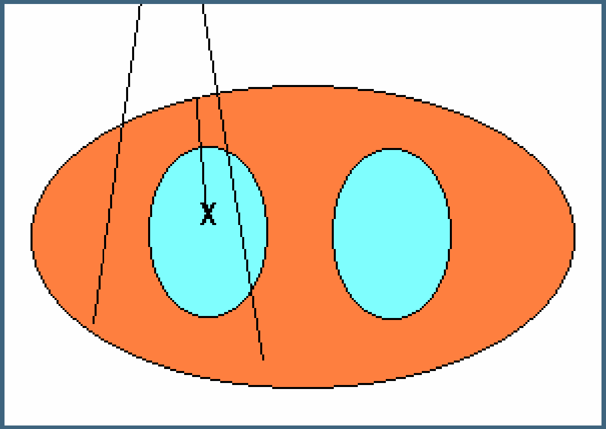
CSA better than PBA!

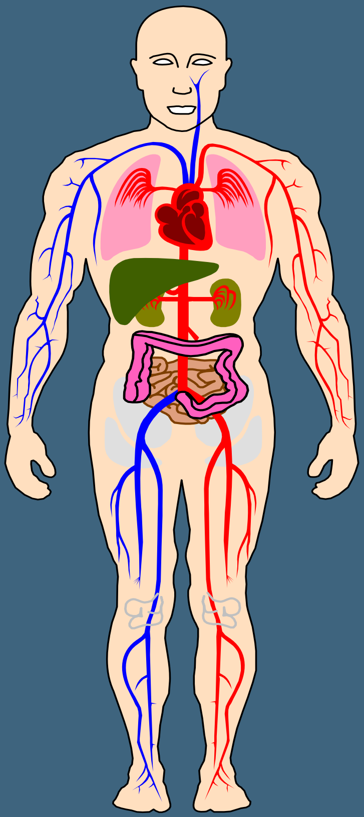
Davidson et al. Med Phys 35: 5434-5439; 2008

Dose Calculation Algorithms

B. Use of Anatomy Data

- Patient's Anatomy
  - As imaged by CT, MR, PET, etc
  - Geometry and density
    - As sensed by algorithm
  - Symmetry assumptions
- 1-D, 2-D, 2.5-D, or 3-D matrix





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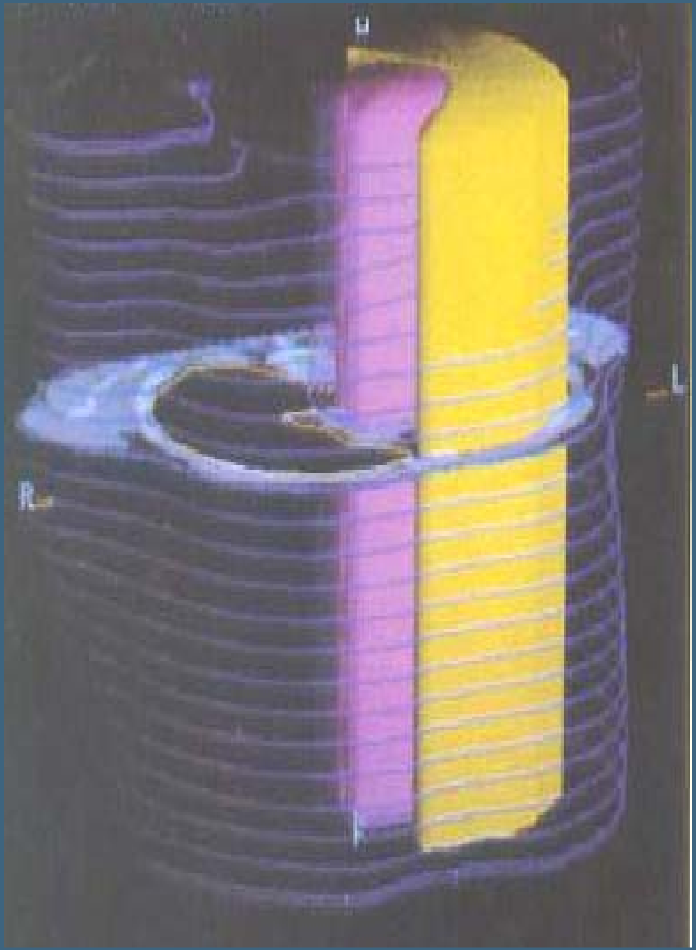
Example Symmetry Assumptions



From Nick Linton - Elekta

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National/International Reports re RTPS

- Geoff Ibbott…

National/International Reports re RTPS

- ICRU 42
  - *Use of Computers in External Beam Radiotherapy Procedures with High Energy Photons and Electrons*
  - 70 pages, 1987
- AAPM Report No. 55 (TG 23)
  - *Radiation Treatment Planning Dosimetry Verification*
  - *271 pages, 1995*

National/International Protocols

American Association of Physicists in Medicine Radiation Therapy Committee Task Group 53: Quality assurance for clinical radiotherapy treatment planning

Benedick Fraass[a)]
University of Michigan Medical Center, Ann Arbor, Michigan

Karen Doppke
Massachusetts General Hospital, Boston, Massachusetts

Margie Hunt
Fox Chase Cancer Center, Philadelphia, Pennsylvania and Memorial Sloan Kettering Cancer Center, New York, New York

Gerald Kutcher
Memorial Sloan Kettering Cancer Center, New York, New York

George Starkschall
M. D. Anderson Cancer Center, Houston, Texas

Robin Stern
University of California, Davis Medical Center, Sacramento, California

Jake Van Dyk
London Regional Cancer Center, London, Ontario, Canada

Med Phys 25:1773-829,1998

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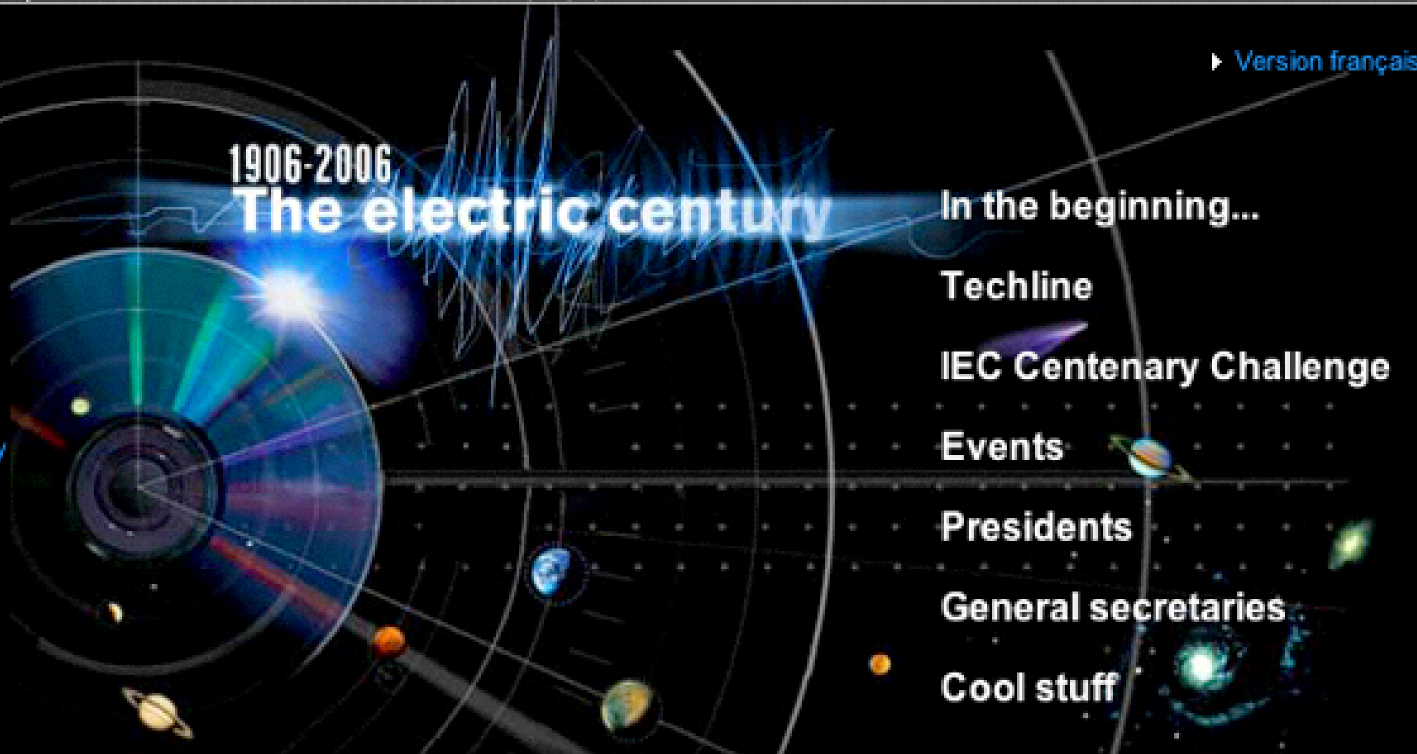
100 YEARS OF THE IEC

Version française

WHAT'S RELATED

- Special IEC community rate for The Economist
- IEC technical committee creation: the first half-century
- Development and growth of IEC technical committees: 1950 to 2006
- 1906 Preliminary Meeting Report
- IEC History: 1906-1956
- IEC Bulletin - 75th anniversary edition
- IEC SI Zone
- 1901-2001, Celebrating the Centenary of SI - Giovanni Giorgi's Contribution and the Role of IEC



In the beginning...
Techline
IEC Centenary Challenge
Events
Presidents
General secretaries
Cool stuff

The IEC came into being on 26-27 June 1906 in London, UK, and ever since has been giving the very best global standards to the world's electrotechnical industries. The IEC thanks industry, government, academia, end-users, and everyone else who has been involved from around the world for 100 years of commitment and partnership.

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The International Electrotechnical Commission

- 68 member nations (including associate members
- Produces standards addressing the design of electrotechnical equipment.
- Safety and performance standards apply to manufacturer’s design and construction
- Compliance tests can be *type tests*, or *site tests*
- Site tests sometimes incorporated into acceptance testing procedures

Adoption of IEC Standards

In US:

- IEC standards (or sections) incorporated into ANSI standards, FDA regulations, NEMA guidelines, etc.
- IEC standards can be used as written; FDA requires vendor to report compliance

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Publications from WG-1

- Equipment for Radiation Therapy
  - Linear Accelerators
  - Cobalt Units (including Gammaknife)
  - Orthovoltage Treatment Units
  - Simulators
  - Brachytherapy Remote Afterloaders
  - Treatment Planning Systems
  - Record & Verify Systems

National/International Protocols

- For manufacturers

NORME INTERNATIONALE
INTERNATIONAL STANDARD

CEI
IEC
62083

Première édition
First edition
2000-11

Appareils électromédicaux – Règles particulières de sécurité pour les systèmes de planification de traitement en radiothérapie

Medical electrical equipment – Requirements for the safety of radiotherapy treatment planning systems

International Electrotechnical Commission (IEC), 2000

IEC 62083 - Safe Operation of Treatment Planning Systems

- Format of displays, units, date & time
- Data limits, transfer
- Saving and archiving data
- Equipment and source model
- Patient model
- Treatment planning
- Dose calculation
- Treatment plan report

National/International Protocols

- ESTRO 2004

QUALITY ASSURANCE OF TREATMENT PLANNING SYSTEMS PRACTICAL EXAMPLES FOR NON-IMRT PHOTON BEAMS

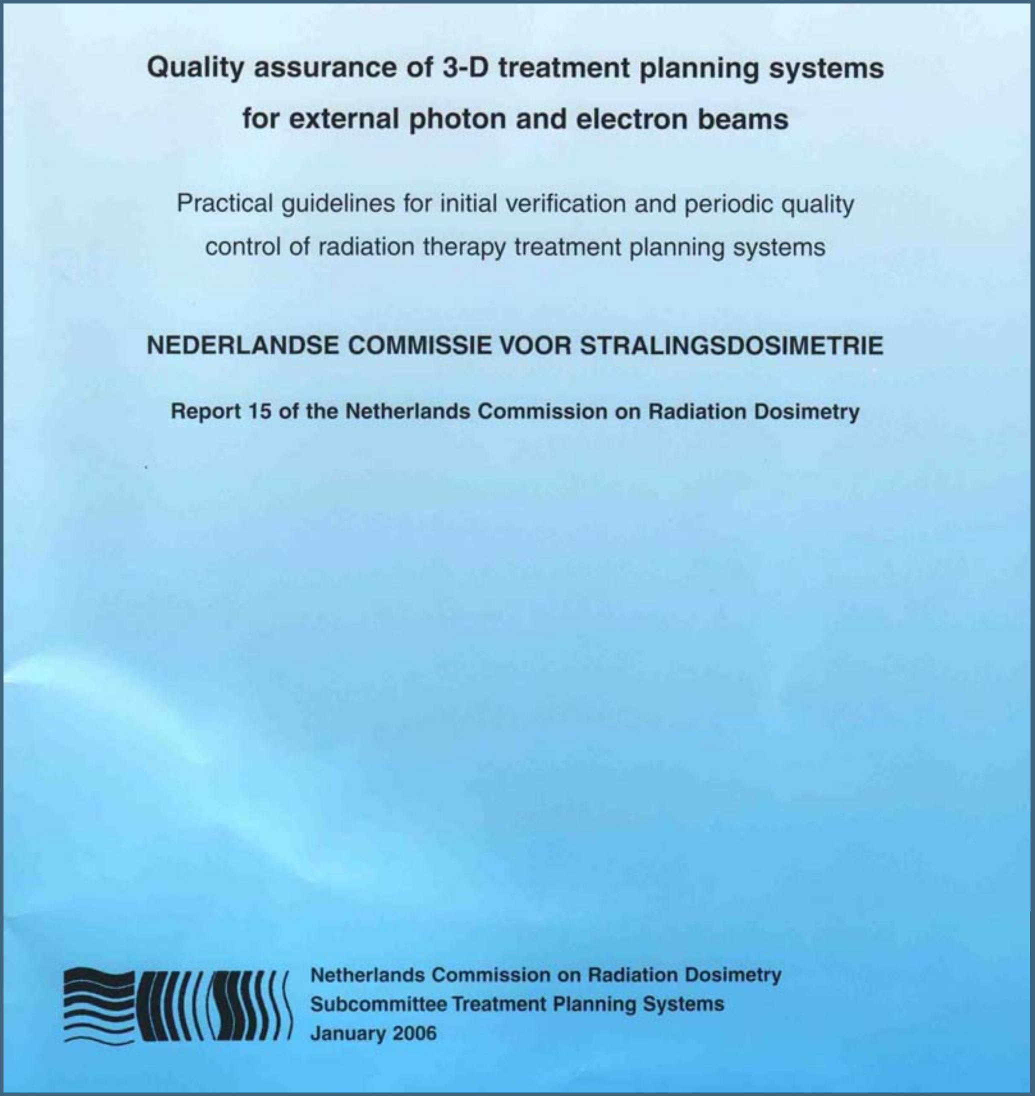
Ben Mijnheer
Agnieszka Olszewska
Claudio Fiorino
Guenther Hartmann
Tommy Knöös
Jean-Claude Rosenwald
Hans Welleweerd

2004 – First edition
ISBN 90-804532-7
© 2004 by ESTRO

Available from ESTRO website:
http://www.estroweb.org/estro/index.cfm

National/International Protocols

- Netherlands Commission on Radiation Dosimetry 2006



Quality assurance of 3-D treatment planning systems for external photon and electron beams

Practical guidelines for initial verification and periodic quality control of radiation therapy treatment planning systems

NEDERLANDSE COMMISSIE VOOR STRALINGSDOSIMETRIE

Report 15 of the Netherlands Commission on Radiation Dosimetry

Netherlands Commission on Radiation Dosimetry
Subcommittee Treatment Planning Systems
January 2006

National/International Protocols

2004

- IAEA TRS-430, 2004

Figure 2

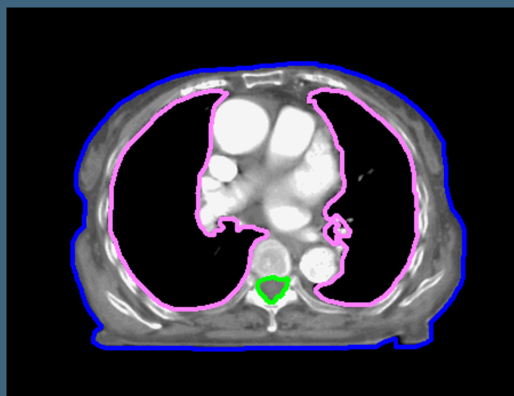
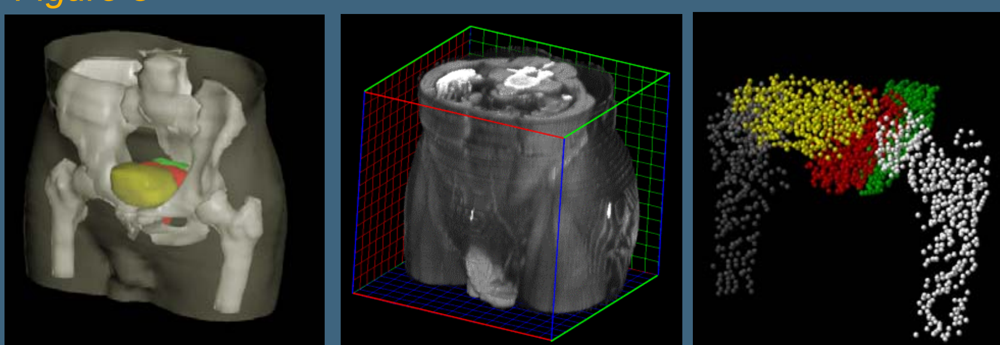
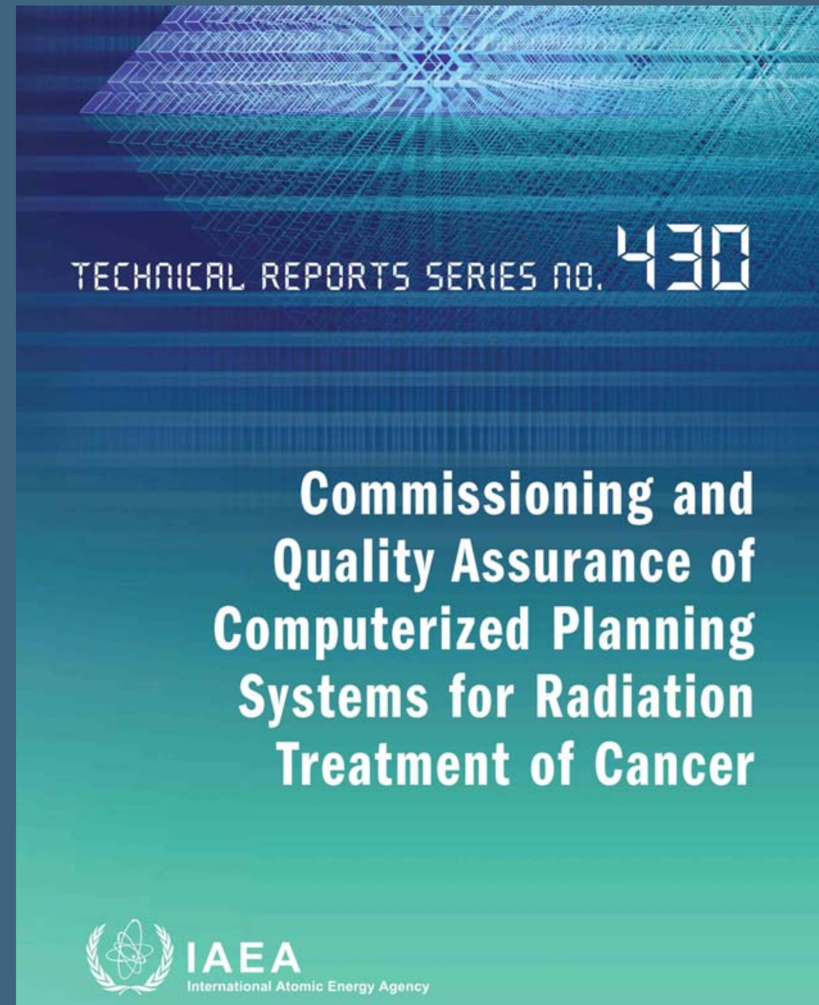


Figure 3

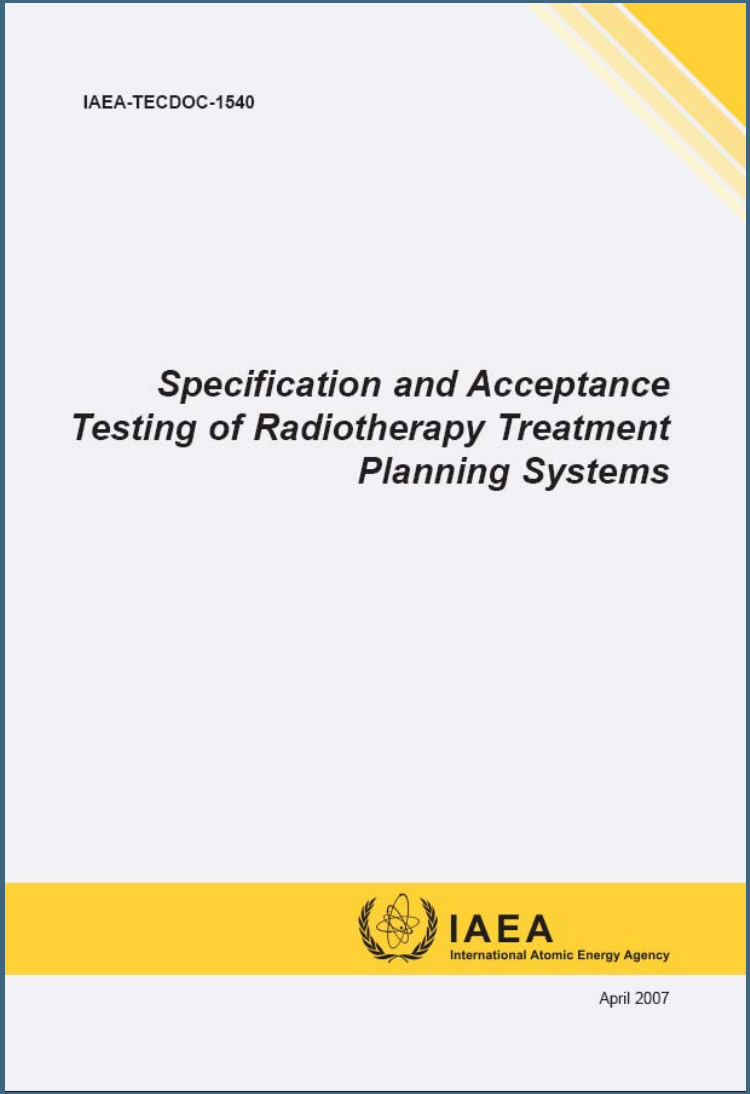




Available in pdf format from:

http://www-pub.iaea.org/MTCD/publications/PDF/TRS430_web.pdf

New Protocol: Acceptance Testing


IAEA-TECDOC-1540

Specification and Acceptance Testing of Radiotherapy Treatment Planning Systems

IAEA
International Atomic Energy Agency

April 2007

- IAEA-TECDOC-1540
  - April 2007
- Contributors:
  - Geoffrey Ibbott
  - Rainer Schmidt
  - Jake Van Dyk
- Scientific Secretary:
  - Stanislav Vatnitsky

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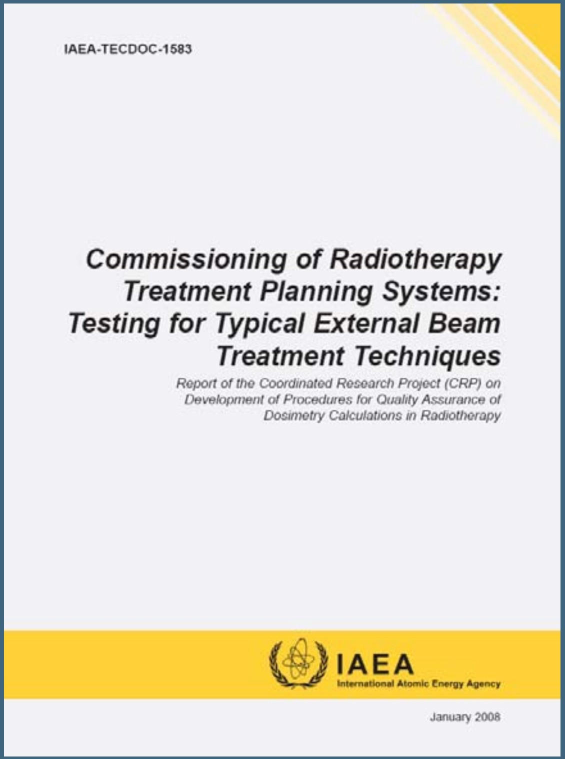
New Protocol: Commissioning

- IAEA Protocol for Commissioning of Radiation Treatment Planning Systems
  - Specific guidelines for IAEA supported systems



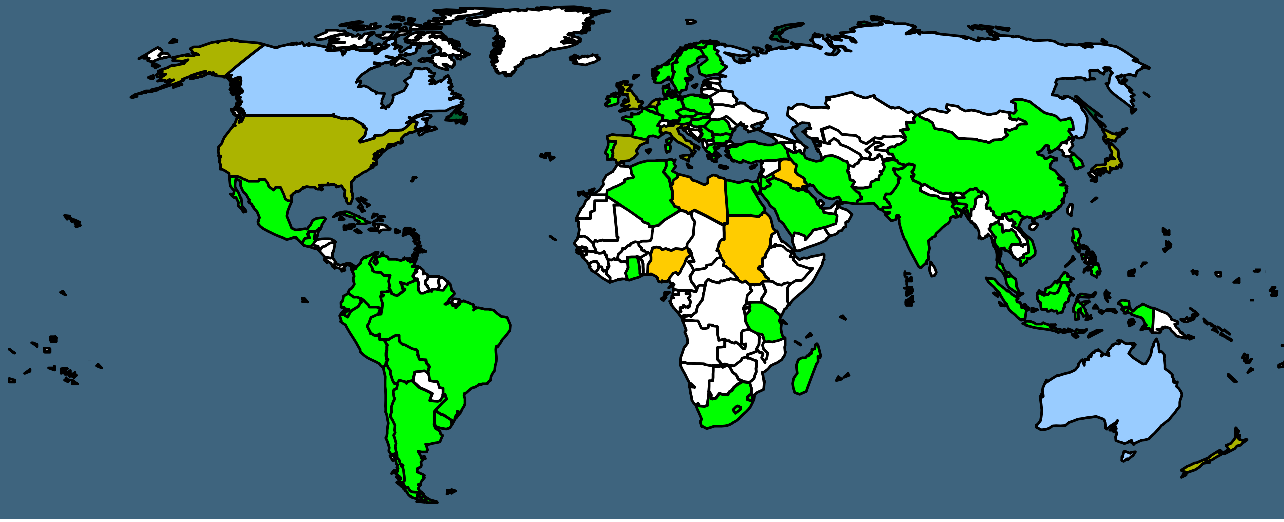
IAEA-TECDOC-1583

Commissioning of Radiotherapy Treatment Planning Systems: Testing for Typical External Beam Treatment Techniques

Report of the Coordinated Research Project (CRP) on Development of Procedures for Quality Assurance of Dosimetry Calculations in Radiotherapy

IAEA
International Atomic Energy Agency

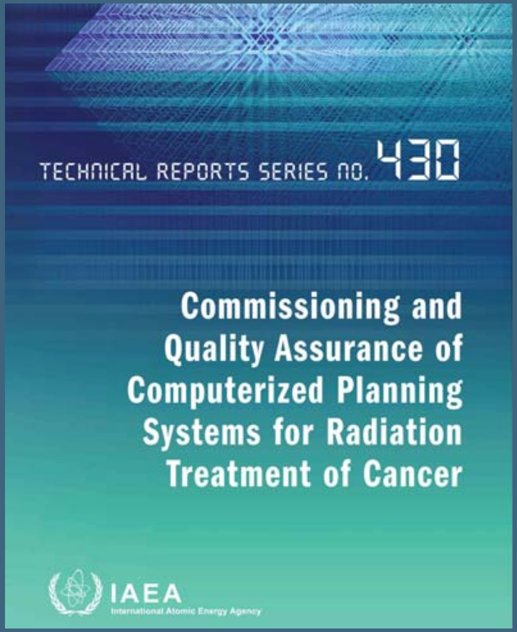
January 2008



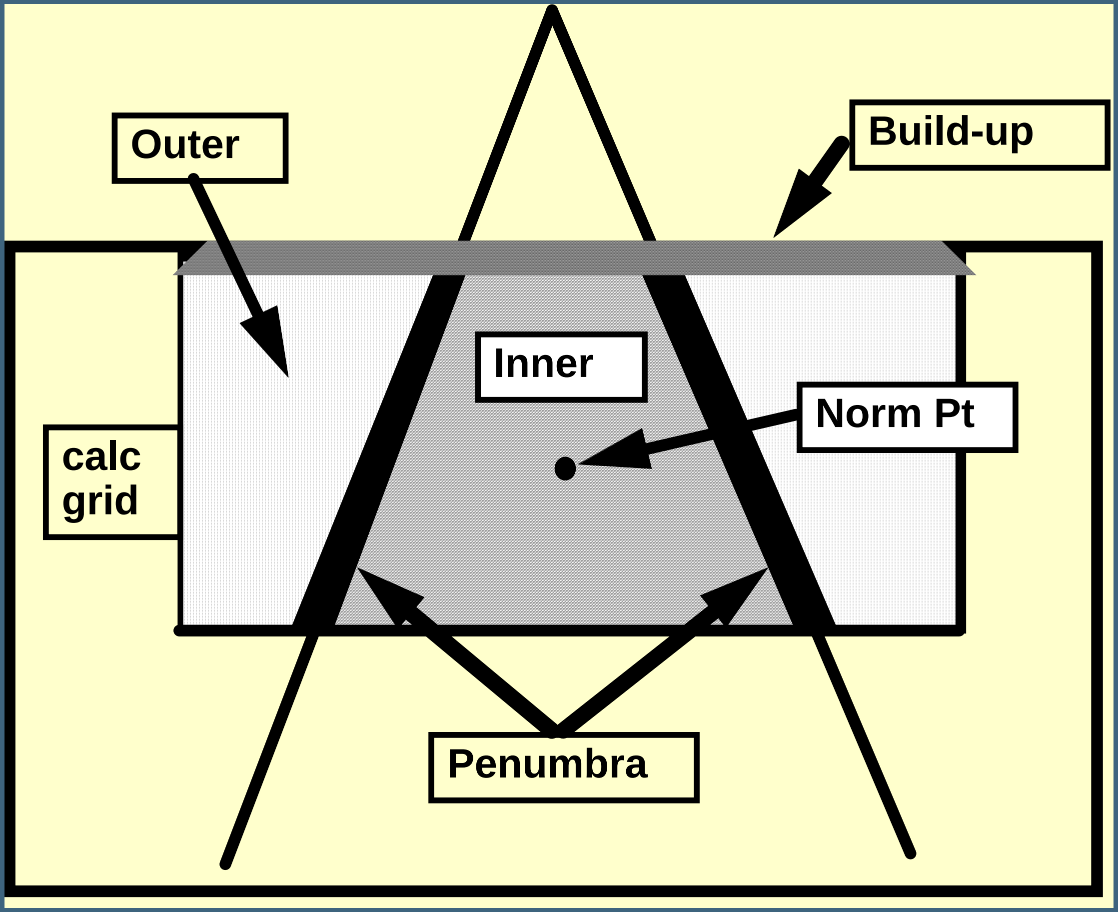
- Regular member
- Affiliated member
- Provisional member

IAEA TRS 430 Contents

1. Introduction
2. Clinical treatment planning process
3. Description of radiation treatment planning systems
4. Algorithms used in radiation treatment planning
5. Quality assessment
6. Quality assurance management
7. Purchase process
8. Acceptance testing
9. Commissioning
10. Periodic quality assurance
11. Patient-specific quality assurance
12. Summary



Quality Assessment
Accuracy Requirements



AAPM TG53

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Sample Criteria of Acceptability

IAEA TRS 430

Situation	Absolute Dose (%)*	Central Ray (%)	Inner Beam (%)	Penumbra (mm)	Outer Beam (%)	Build-up Region (%)
A. Homogeneous Phantoms						
Square fields	0.5	1	1.5	2	2	20
Rectangular fields	0.5	1.5	2	2	2	20
Asymmetric fields	1	2	3	2	3	20
Blocked fields	1	2	3	2	5	50
MLC-shaped fields	1	2	3	3	5	20
Wedged fields	2	2	5	3	5	50
External surface variations	0.5	1	3	2	5	20
SSD variations	1	1	1.5	2	2	40
B. Inhomogeneous Phantoms**						
Slab inhomogeneities	3	3	5	5	5	-
3-D inhomogeneities	5	5	7	7	7	-

* Absolute dose values at the normalization point are relative to a standard beam calibration point.

** Excluding regions of electronic disequilibrium.

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Accuracy Requirements for IMRT

- Palta, J. 2003 AAPM Summer School Proceedings

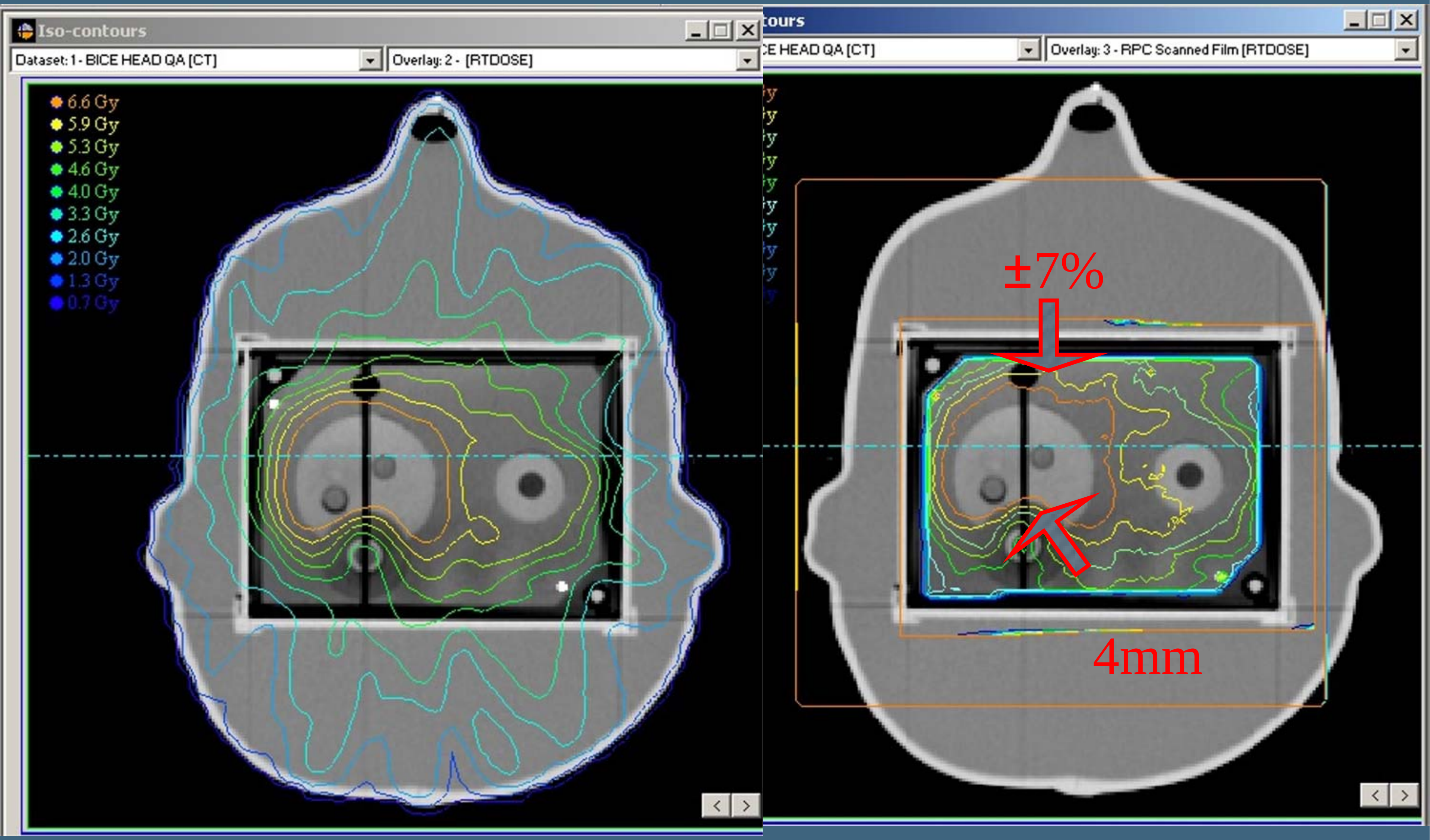
Proposed Values of the Confidence Limits and Action levels for IMRT Planning

Region	Confidence Limit* (P=0.05)	Action Level
δ_1 (high dose, small dose gradient)	±3%	±5%
δ_2 (high dose, large dose gradient)	10% or 2 mm DTA⊕	15% or 3 mm DTA⊕
δ_3 (low dose, small dose gradient)	4%	7%
$\delta_{90\text{-}50\ \%}$ (dose fall off)	2 mm DTA	3 mm DTA

* Mean deviation used in the calculation of confidence limit is δ_i = 100% X ($D_{calc.}$ – $D_{meas.}$/$D_{prescribed}$)

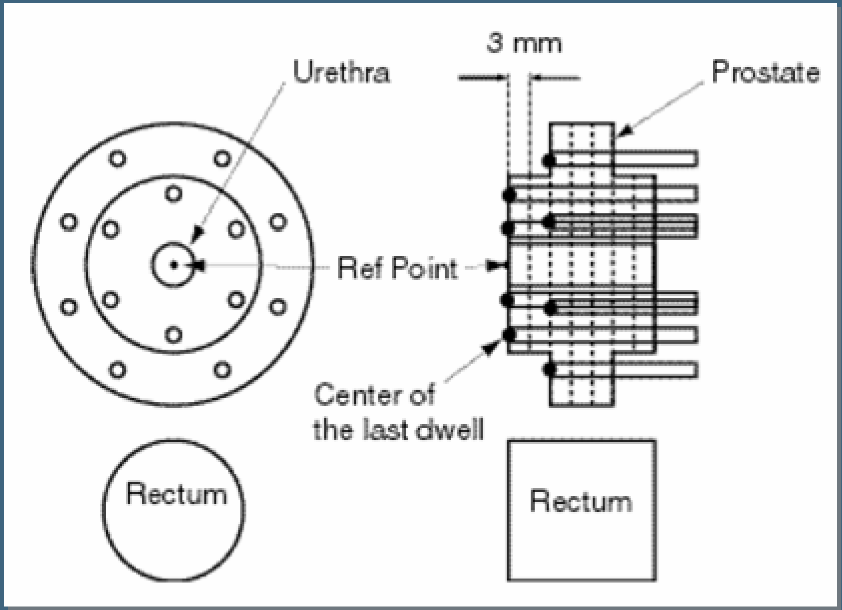
⊕ DTA = Distance to agreement

Accuracy Requirements for IMRT



Accuracy Requirements for Brachytherapy

- AAPM recommends ± 2% calculation accuracy, and grid spacing 1mm x 1mm x 1mm (TG-43 update 2004)
- RPC requires agreement with benchmark plans within 5%, and 5% or 0.5 mm for single source calculations



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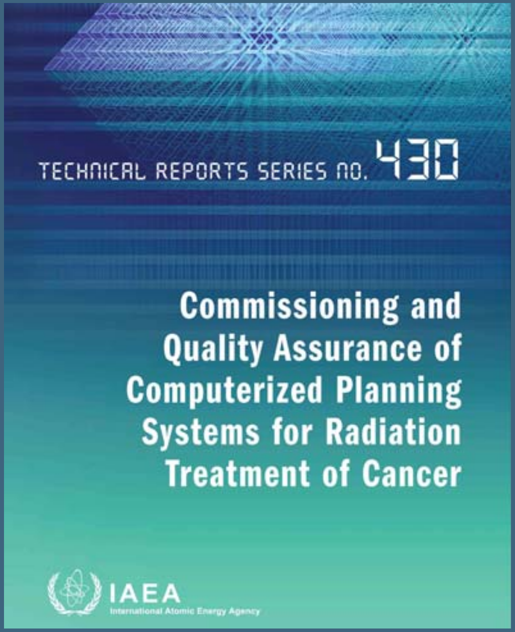
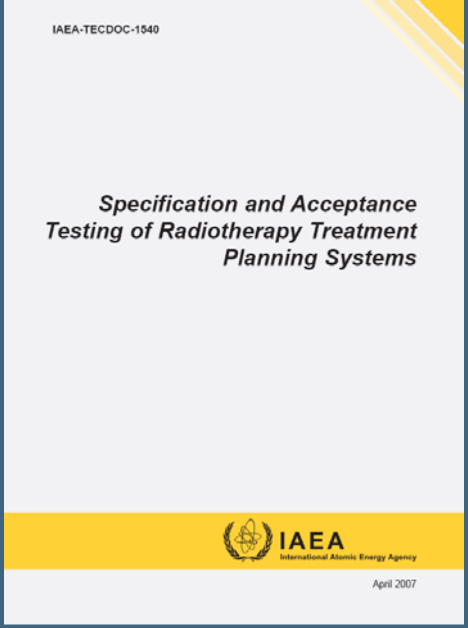
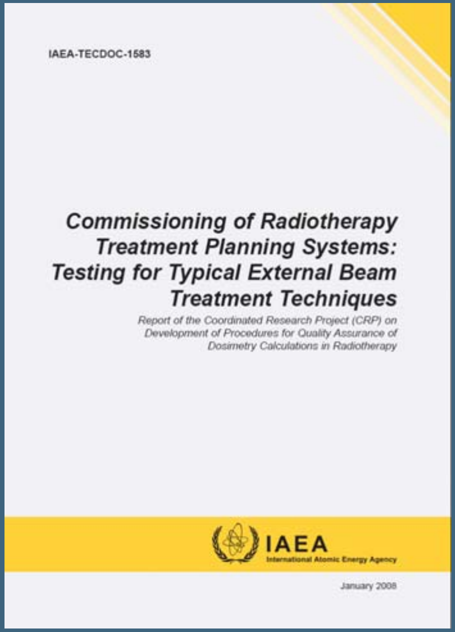
IAEA TRS 430 Dose Calculations & Acceptance Testing

- Jake Van Dyk…







IAEA TRS-430 Dose Calculation Algorithms

- Questions users should ask

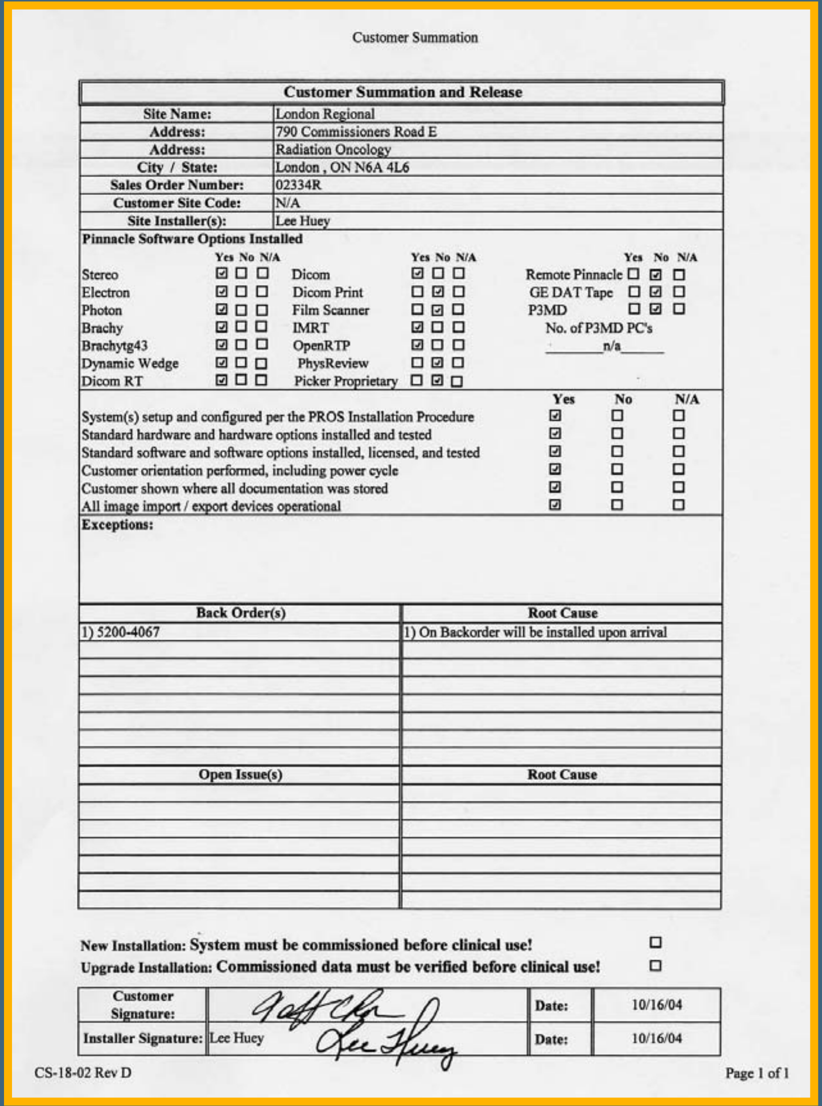
TABLE 11. EXTERNAL BEAM DOSE CALCULATION ALGORITHM: DOSE IN WATER-LIKE MEDIUM WITHOUT A BEAM MODIFIER

	Question
General principle of relative dose calculation	From interpolation in tables? From analytical functions? By addition of primary and scatter components? By superposition of pencil beam kernels? By superposition of point dose kernels? By Monte Carlo calculation? From a combination of the above possibilities?
If an integration (or superposition or convolution) algorithm takes place	What are the shape and dimensions of the volume elements? What are the limits of the integration volume? Is it applied differently for each of the dose components (i.e. primary, scatter, etc.)? Is there any correction for spectral modifications with depth?
Influence of flattening filter	Is there a correction for intensity and quality variation across the beam (horns)? Is there a correction for scatter radiation from the head and flattening filter (extrafocal)?
Influence of main collimator (photons) and/or applicator (electrons)	What is the model used to describe the profile in the penumbra region? How is it adjusted to match the actual measurements? Is there a difference between the x and y collimator pairs?
Dose in the buildup region	Is there any specific model to describe the dose in the buildup region? Is it sensitive to patient surface obliquity? How? Is it sensitive to beam modifiers, including block trays? How?

Acceptance Testing

- What happens in reality!
  - Catalogue delivered components
    - Hardware
    - Software
  - Test components for functionality
  - Sign acceptance document

That is how acceptance should not be done!



Customer Summation

Customer Summation and Release	
Site Name:	London Regional
Address:	790 Commissioners Road E
Address:	Radiation Oncology
City / State:	London , ON N6A 4L6
Sales Order Number:	02334R
Customer Site Code:	N/A
Site Installer(s):	Lee Huey

Pinnacle Software Options Installed

	Yes	No	N/A		Yes	No	N/A		Yes	No	N/A
Stereo	☑	☐	☐	Dicom	☑	☐	☐	Remote Pinnacle	☐	☑	☐
Electron	☑	☐	☐	Dicom Print	☐	☑	☐	GE DAT Tape	☐	☑	☐
Photon	☑	☐	☐	Film Scanner	☐	☑	☐	P3MD	☐	☑	☐
Brachy	☑	☐	☐	IMRT	☑	☐	☐	No. of P3MD PC's			
Brachytg43	☑	☐	☐	OpenRTP	☑	☐	☐	n/a			
Dynamic Wedge	☑	☐	☐	PhysReview	☐	☑	☐				
Dicom RT	☑	☐	☐	Picker Proprietary	☐	☑	☐				

	Yes	No	N/A
System(s) setup and configured per the PROS Installation Procedure	☑	☐	☐
Standard hardware and hardware options installed and tested	☑	☐	☐
Standard software and software options installed, licensed, and tested	☑	☐	☐
Customer orientation performed, including power cycle	☑	☐	☐
Customer shown where all documentation was stored	☑	☐	☐
All image import / export devices operational	☑	☐	☐

Exceptions:

Back Order(s)	Root Cause
1) 5200-4067	1) On Backorder will be installed upon arrival

Open Issue(s)	Root Cause

New Installation: System must be commissioned before clinical use! ☐
Upgrade Installation: Commissioned data must be verified before clinical use! ☐

Customer Signature:	[signature]	**Date:**	10/16/04
Installer Signature:	Lee Huey [signature]	**Date:**	10/16/04

CS-18-02 Rev D — Page 1 of 1

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How Should Acceptance Be Done?

- IAEA Protocol
  - Developed 14-18 March 2005 – Published April 2007
    - Consultants
      - *Geoff Ibbott, RPC/MD Anderson CC, Texas, USA*
      - *Rainer Schmidt, Hanover, Germany*
      - *Jake Van Dyk, London, Ontario, Canada*
      - *Stan Vatnitsky, Scientific Secretary, IAEA*
- Reference material
  - IEC 62083
  - IAEA TRS-430
  - Standard radiation data set

NORME
INTERNATIONALE

INTERNATIONAL
STANDARD

CEI
IEC

62083

Première édition
First edition
2000-11

**Appareils électromédicaux –
Règles particulières de sécurité
pour les systèmes de planification
de traitement en radiothérapie**

**Medical electrical equipment –
Requirements for the safety of
radiotherapy treatment planning systems**

From IEC 62083 (2000)

- *"… This standard defines requirements to be complied with by MANUFACTURERS in the design and construction of an RTPS in order to provide protection against the occurrence of such HAZARDS."*

This has not been demonstrated for the past ~8 years!!

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Tests Defined by IEC

- **Type test**: *"For a particular design of device or equipment, a test by the manufacturer to establish compliance with specified criteria."*

- **Site test**: *"After installation, test of an individual device or equipment to establish compliance with specified criteria." "Note: The recommended replacement is ACCEPTANCE TEST."*

- Site test = Acceptance test

Testing Process Recommended by IAEA

- Manufacture to perform series of type tests
- Type test results should be documented and made available to user
- Site (acceptance) tests should be a subset of type tests performed at the time of TPS installation
  - Results compared to results of type tests

Examples of Type Tests in IEC 62083

Clause	Requirement	Compliance?	
7	**General requirements for operational safety**	**Yes**	**No**
7.1	Distances and linear dimensions		
7.2	RADIATION quantities		
7.3	Date and time format		
7.4	Protection against unauthorized use		
7.5	Data limits		
7.6	Protection against unauthorized modification		
7.7	Correctness of data transfer		
7.8	Coordinate systems and scales		
7.9	Saving and archiving data		

Next slide

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Type Test Example

- **7.1 Distances and linear dimensions**
- Distance measurements and linear dimensions shall be indicated in centimetres or in millimetres but not both.

- All values of linear measurements requested, DISPLAYED, or printed shall include their units.

- *Compliance is checked by inspection of the DISPLAY and output information.*

Equipment and Dosimetric Modelling

Clause	Requirement	Compliance?	
8	**RADIOTHERAPY TREATMENT EQUIPMENT and BRACHYTHERAPY SOURCE MODELLING**	**Yes**	**No**
8.1	General		
8.2	Dosimetric information		
8.3	EQUIPMENT MODEL, BRACHYTHERAPY SOURCE MODEL acceptance		
8.4	EQUIPMENT MODEL, BRACHYTHERAPY SOURCE MODEL deletion		

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Anatomy Modelling

Clause	Requirement	Compliance?	
9	**ANATOMY MODELLING**	**Yes**	**No**
9.1	Data acquisition		
9.2	Coordinate systems and scales		
9.3	Contouring of regions of interest		
9.4	PATIENT ANATOMY MODEL acceptance		
9.5	PATIENT ANATOMY MODEL deletion		

Absorbed Dose Distribution Calculation

Clause	Requirement	Compliance?	
11	**ABSORBED DOSE distribution calculation**	**Yes**	**No**
11.1	**Algorithms used**		
11.2	**Accuracy of algorithms**		

- AAPM Report 55, TG23, 1995
- MILLER D.W., BLOCH P.H., CUNNINGHAM J.R. Radiation treatment planning dosimetry verification. AAPM Report Number 55, American Institute of Physics, New York (1995).
- Netherlands Commission on Radiation Dosimetry
- BRUINVIS, I.A.D. *et al.* Quality Assurance of 3-D Treatment Planning Systems for External Photon and Electron Beams. 2006.
- VENSELAAR J., WELLEWEERD H. Application of a test package in an intercomparison of the photon dose calculation performance of treatment planning systems used in a clinical setting, Radiother.Oncol, 60, (2001) 203-213.
- DAVIDSON *et al.* Heterogeneity dose calculation accuracy in IMRT: Study of five commercial treatment planning systems using an anthropomorphic thorax phantom. Med Phys 35: 5434-5439; 2008

Type Tests

- Elekta
  - 6, 10, 18 MV
    - Venselaar & Welleweerd
  - Co-60
    - AKH, Vienna

Venselaar & Welleweerd Radioth Oncol 60: 203-213, 2001.

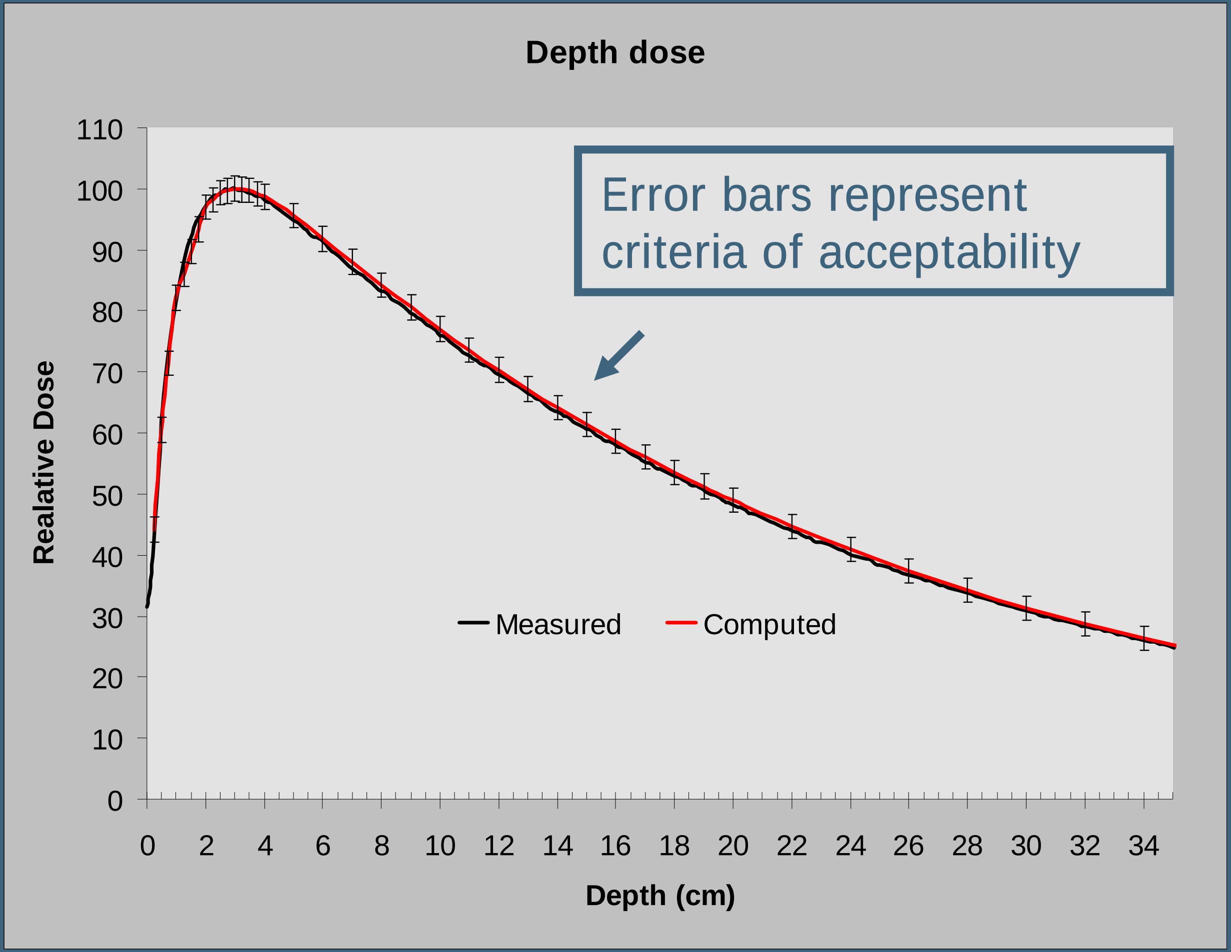
Table 1
Correspondence of the NCS test set and the AAPM task group 23 test set[a]

NCS	Short description of the test (dimensions in cm)	AAPM TG 23
1a	Square field, 5 × 5	1
1b	Square field, 10 × 10	1
1c	Square field, 25 × 25	1
2a	Rectangular field, 5 × 25	2
2b	Rectangular field, 25 × 5	2
3	Square field, 10 × 10, *SSD* = 85	3
4	Square field, 9 × 9, wedge	4
5	Square field, 16 × 16, central block	5
6	Square field, 10 × 10, off-axis	6
7	Square field, 16 × 16, blocked to L-shaped field (irregular)	7
8a	Square field, 6 × 6, lung inhomogeneity	8
8b	Square field, 16 × 16, lung inhomogeneity	8
8c	Square field, 16 × 16, bone inhomogeneity	8
9	Square field, 10 × 10, oblique incidence	9
10a	Square field, 10 × 10, half phantom ('missing tissue')	–
10b	Square field, 20 × 20, half phantom ('missing tissue')	–
11	Asymmetrical field, 15 × 15; geometric radiation field centre at: 7.5,0; 0,7.5; 7.5,7.5	–
12	Asymmetrically wedged field, 15 × 15; geometric radiation field centre at: ±7.5,0; 0,7.5; ±7.5,7.5	–

[a] Tests 10–12 were not included in the original set.

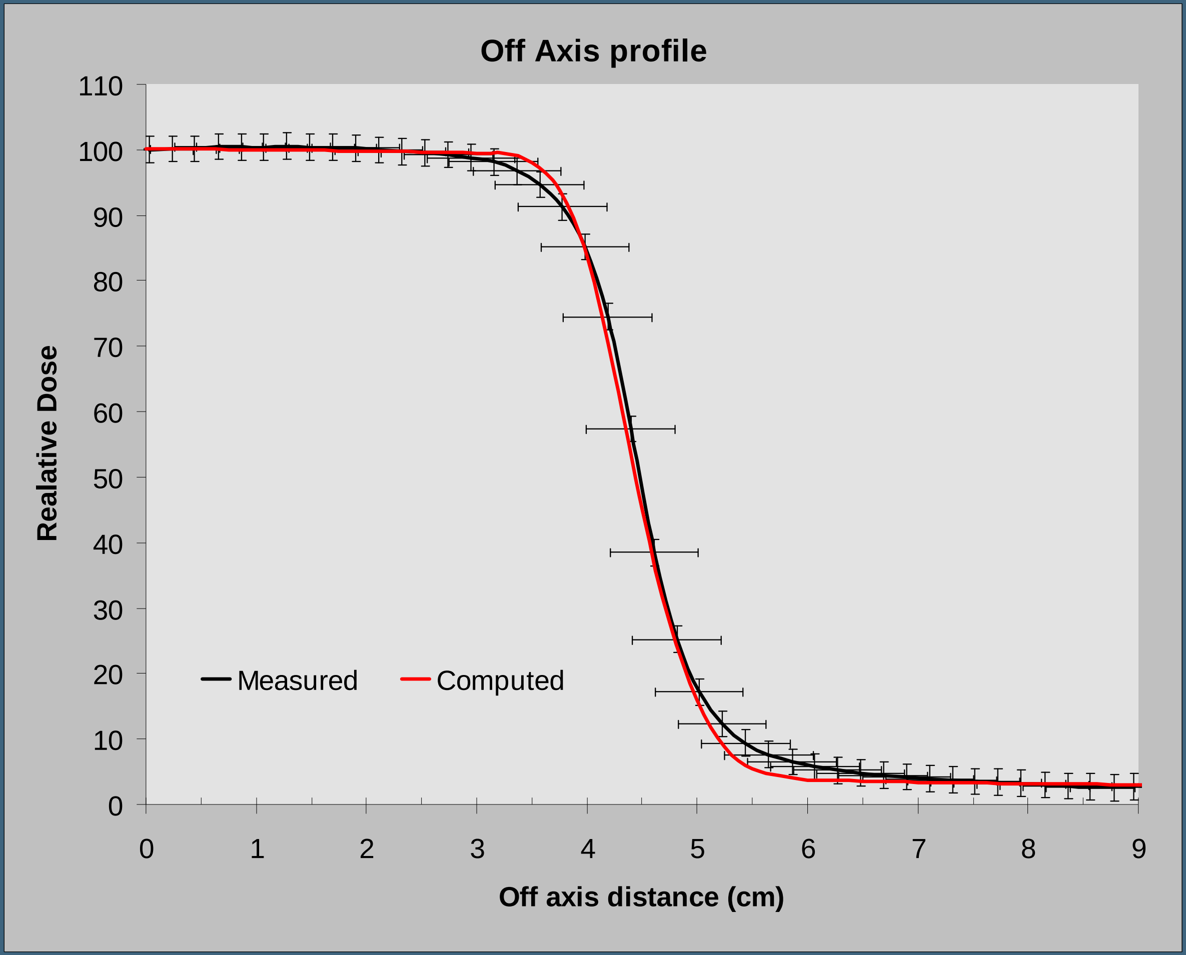
Sample Type Test

- **AAPM Report 55**
- Therac 20 (18MV)
- SSD test case
- SSD=85 cm SAD=100 cm
- Field size 10x10
- Central Axis Comparison
- Measured vs Pencil beam
- +/- 2%



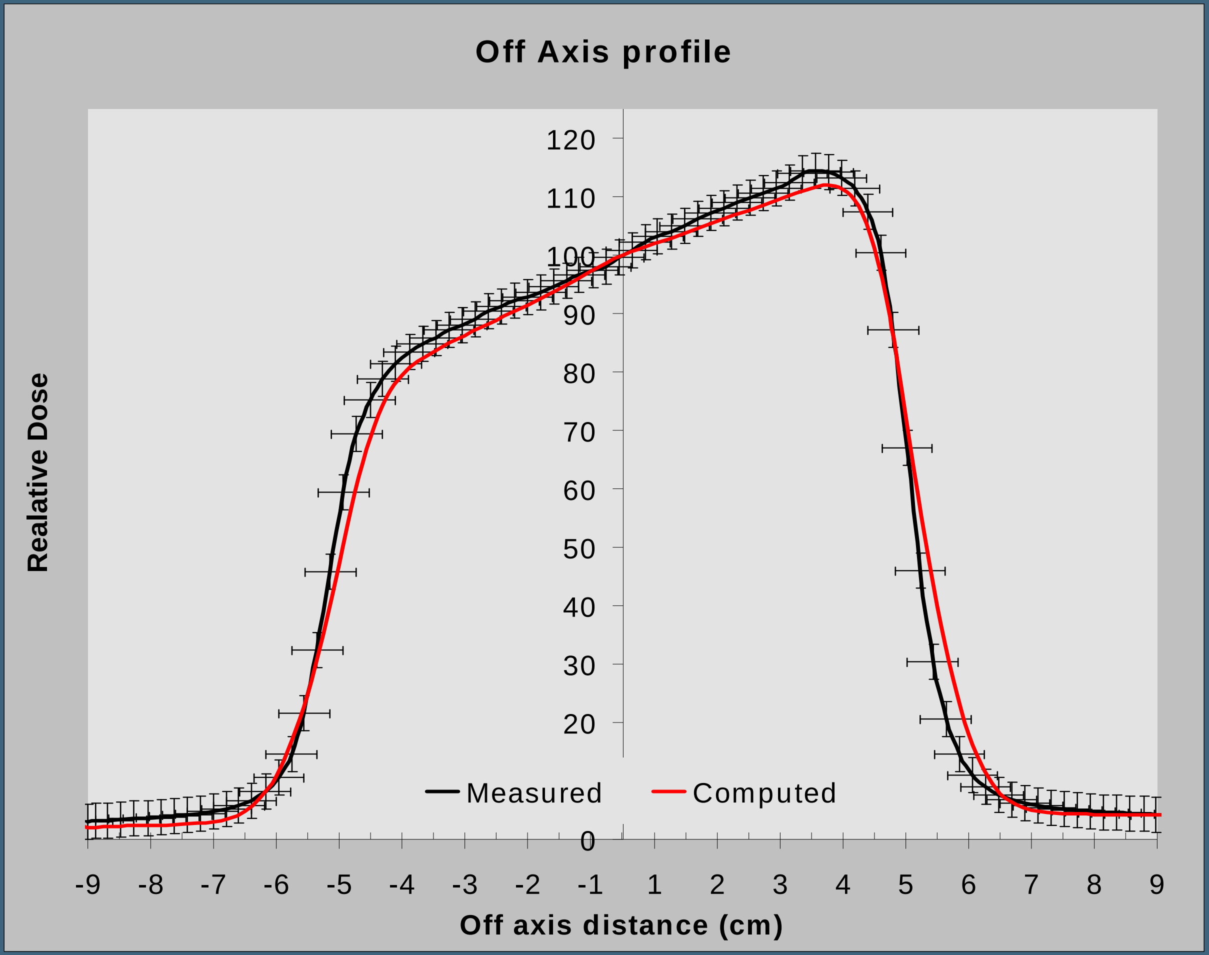
Sample Type Test

- **AAPM Report 55**
- Therac 20 (18MV)
- SSD test case
- SSD=85 cm
  SAD=100 cm
- Field size 10x10
- Profile Comparison
- Depth 3 cm
- Measured vs Pencil beam
- +/- 4 mm.
- +/- 2%



Sample Type Test : Test 4

- **AAPM Report 55**
- Therac 20 (18MV)
- Wedge test case
- SSD=SAD=100cm
- Field size 9x9
- 45º wedge
- Profile Comparison
- Depth 3 cm
- Measured vs Pencil beam
- +/- 4 mm.
- +/- 2%



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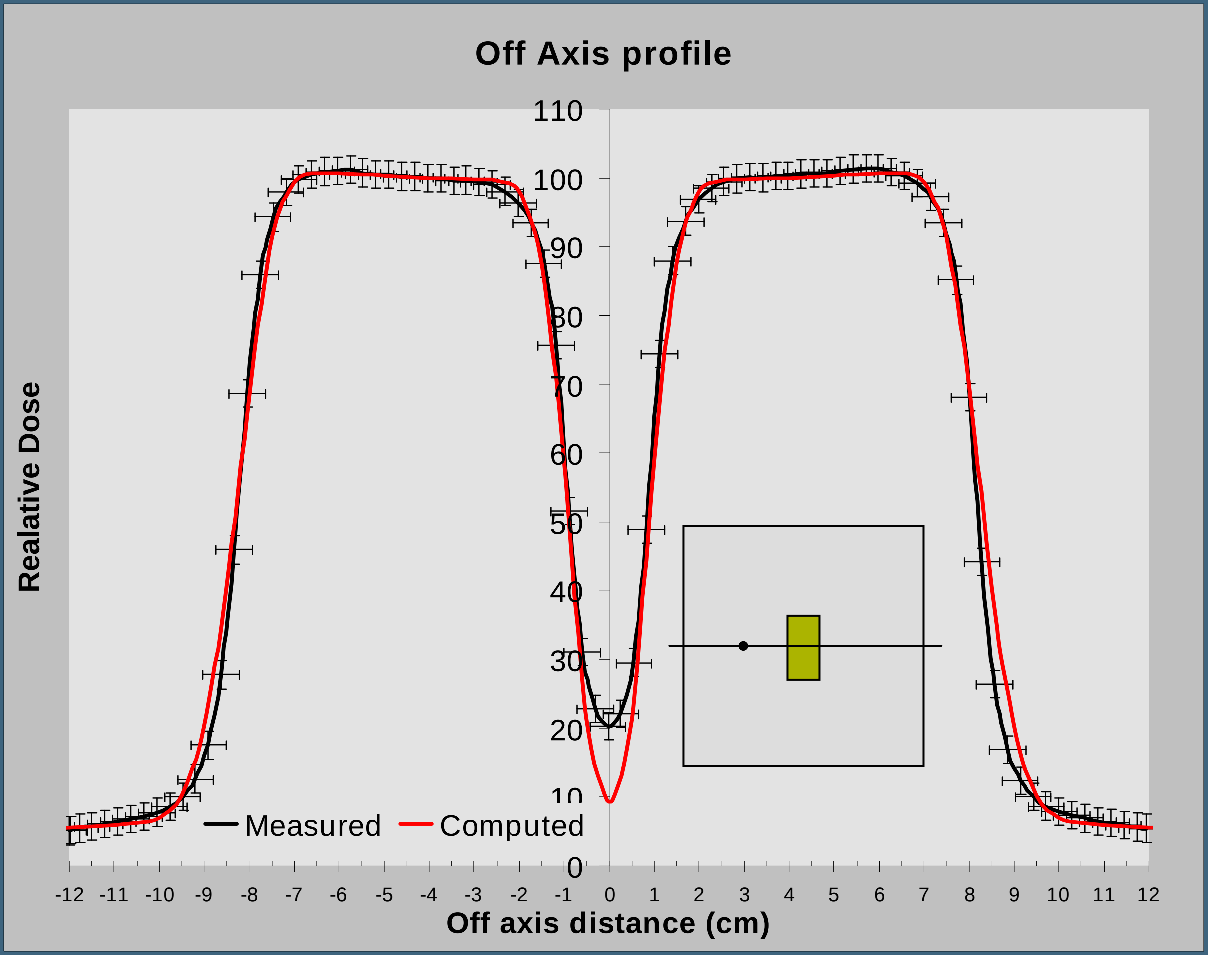
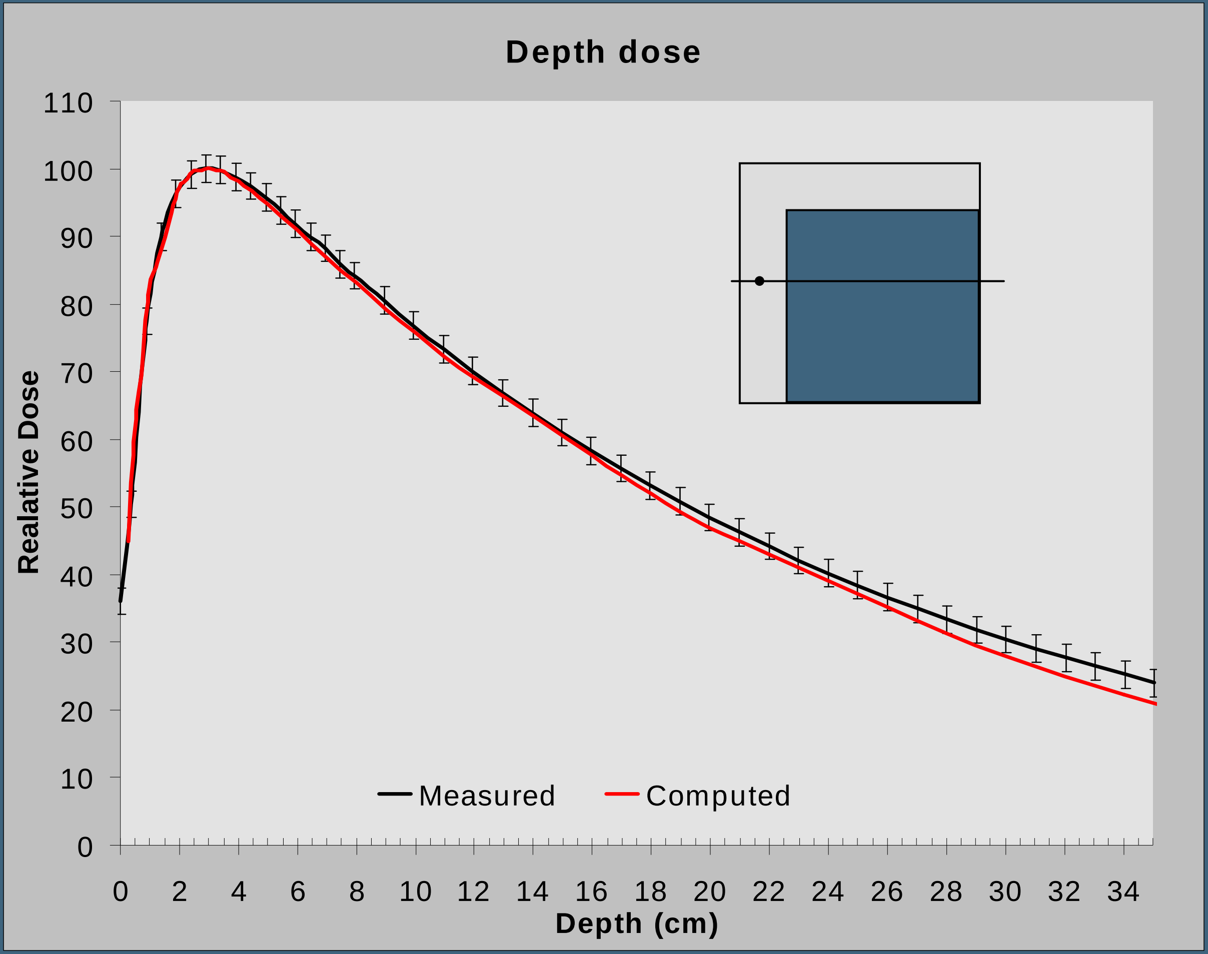
Sample Type Test : Test 5

- **AAPM Report 55**
- Therac 20 (18MV)
- Central axis block test case
- SSD=SAD=100cm
- Field size16x16
- 1x4x7 cm (w,l,t) block at the block tray
- Profile comparison
- 3cm depth
- Measured vs Pencil beam
- +/- 4 mm
- +/- 2%



Sample Type Test : Test 7

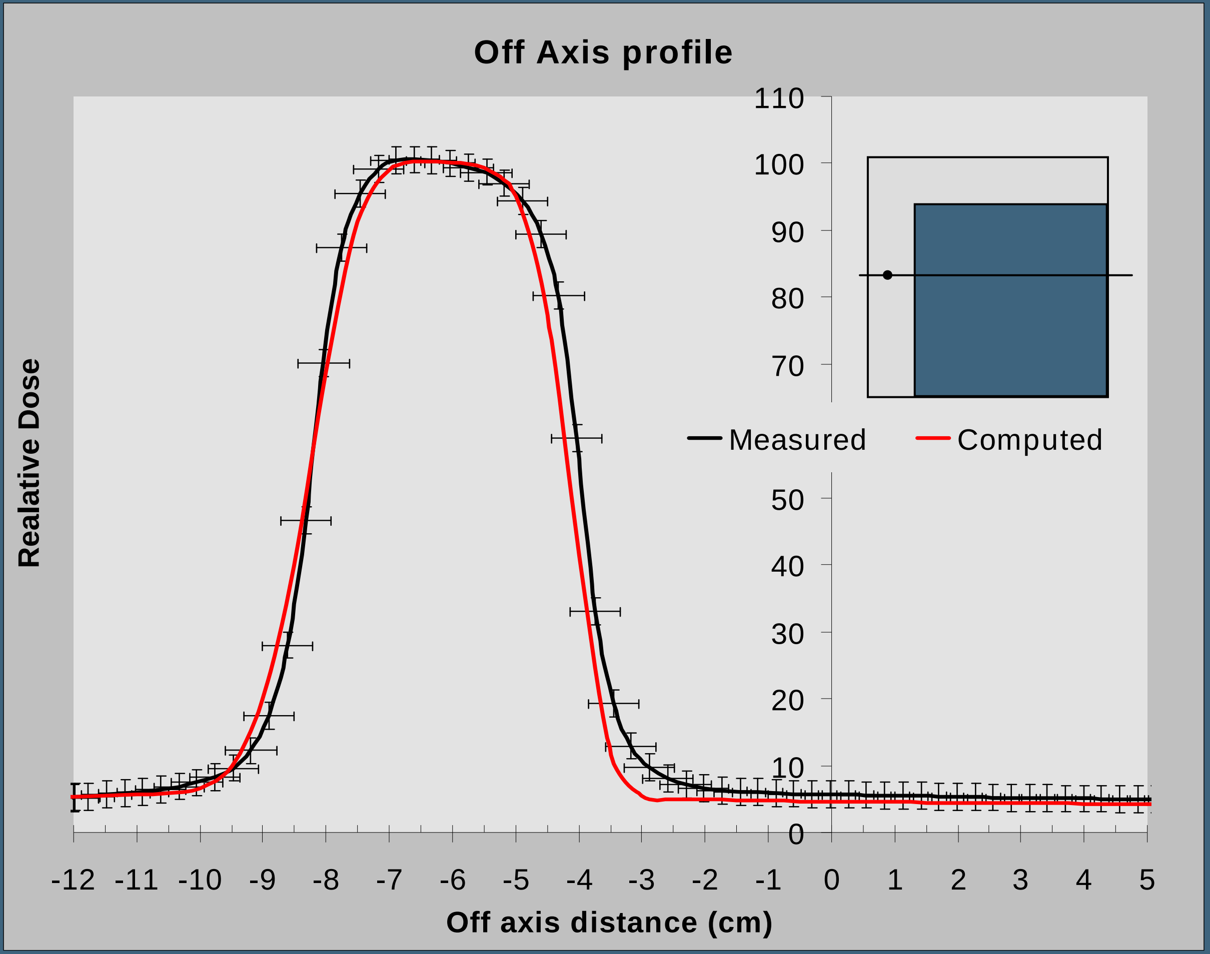
- **AAPM Report 55**
- Therac 20 (18MV)
- Irregular field test case
- SSD=SAD=100cm
- Field size16x16
- 12x12 (w,l) block at the block tray
- Depth dose Comparison -6 cm form the central axis
- Measured vs Pencil beam
- +/- 2%



2008-11-30
RC-122 RSNA

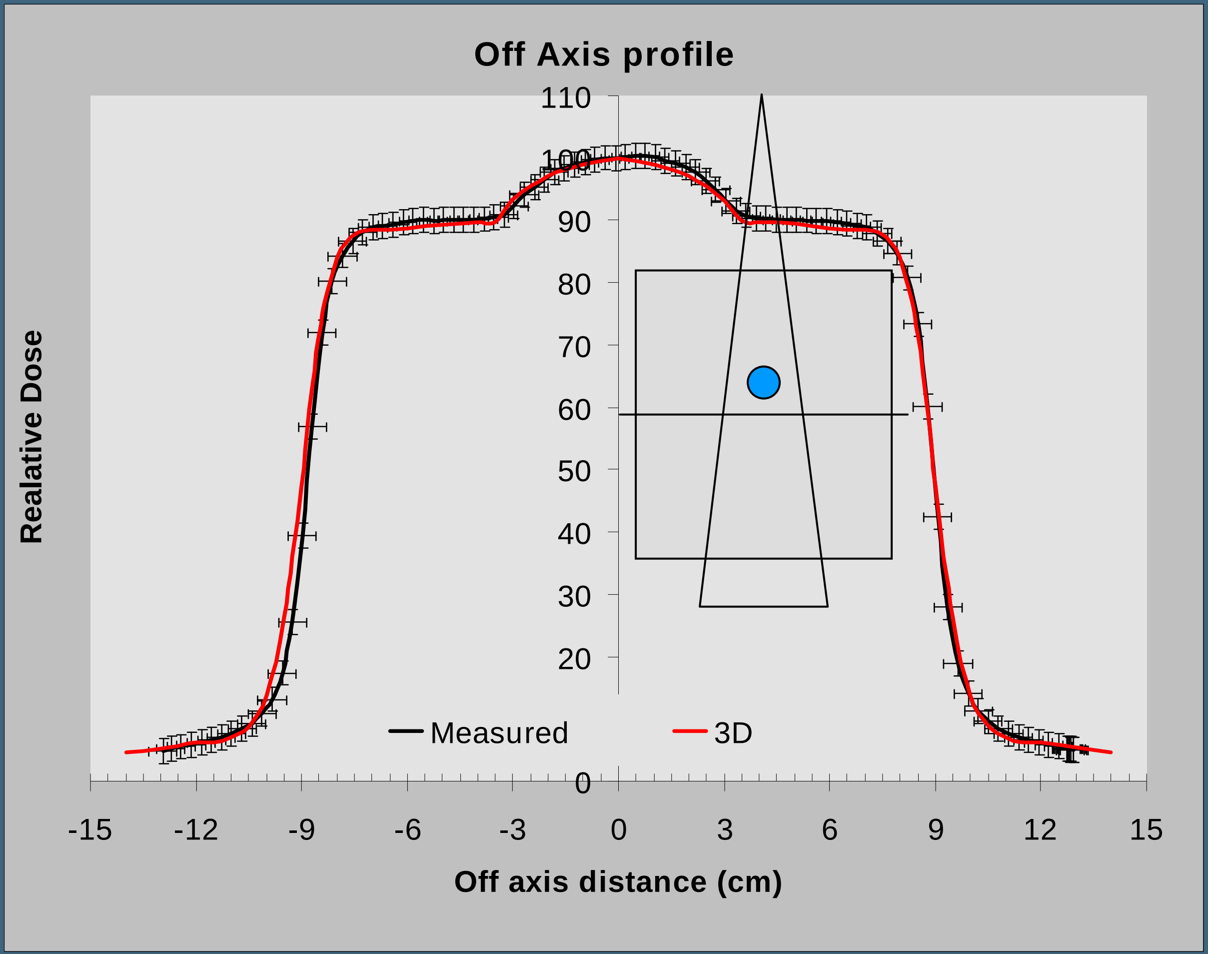
Sample Type Test : Test 4

- **AAPM Report 55**
- Therac 20 (18MV)
- Irregular field test case
- SSD=SAD=100cm
- Field size16x16
- 12x12 (w,l) block at the block tray
- Profile Comparison
- 3 cm depth
- Measured vs Pencil beam
- +/- 4 mm
- +/- 2%

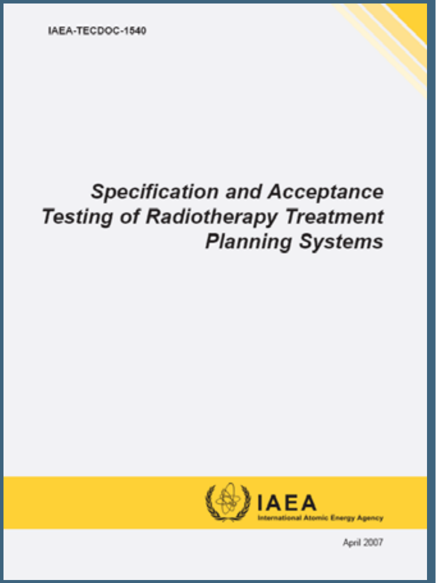


Sample Type Test : Test 8b

- **AAPM Report 55**
- Therac 20 (18MV)
- ***Lung*** Inhomogeneity test
- SSD=SAD=100cm
- Field size16x16
- 6x12cm (w,l) lung cylinder at 8 cm deep, 0.29g/cc
- Profile Comparison
- Depth 12 cm
- Measured vs Pencil beam with EQTAR
- +/- 4mm
- +/- 2%



Summary: Testing Process Recommended by IAEA


IAEA-TECDOC-1540

Specification and Acceptance Testing of Radiotherapy Treatment Planning Systems

IAEA
International Atomic Energy Agency

April 2007

- Manufacturer to perform series of "type tests"
- Type test results should be documented and made available to user
- "Site (acceptance) tests" should be a subset of type tests performed at the time of RTPS installation
  - Results compared to results of type tests
- ***Software upgrades***
- Type tests to be repeated and document by vendor
- Some site tests to be repeated by user
  - Depends on nature of upgrade

Acceptance Sign Off: Based on IAEA Acceptance Protocol

This is to certify that version ______________________________ of the RTPS software

Software version

produced by ____

Name of manufacturer

is compliant with the standards described in Section 5 of this IAEA protocol.

Company representative ____________ ___________ ________ __________

Name Signature Date City

The type tests described above were explained to my satisfaction:

User/purchaser representative _____________ ________________ _______ __________

Name Signature Date City

2008-11-30
RC-122 RSNA

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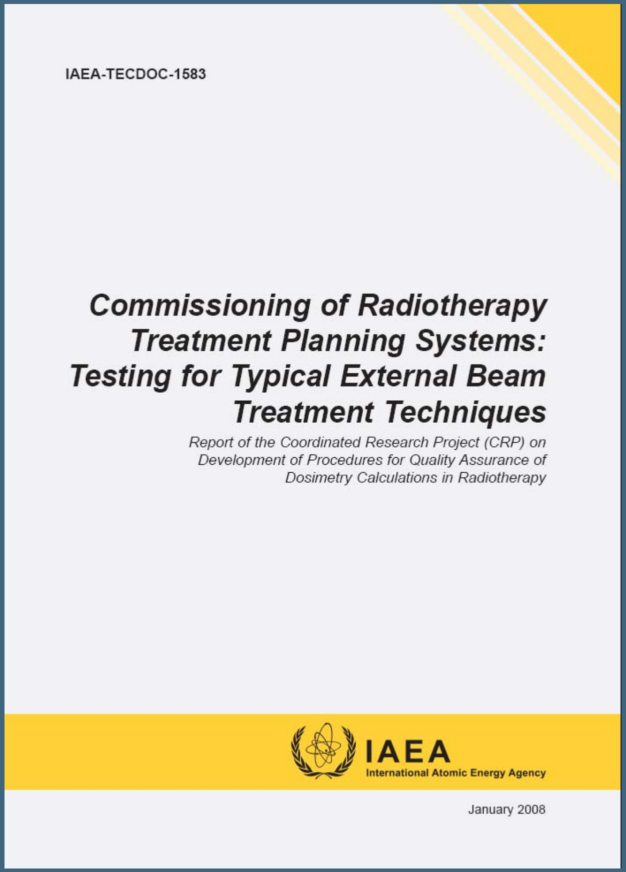
Commissioning

- Prepare system for clinical use
  - Provides experience/training for users
  - Enter appropriate measured data
    - %DD, TAR, TPR, beam profiles, wedge profiles, attenuation data, output factors, etc
  - Perform series of commissioning tests
  - Tests algorithms
    - Provides capabilities & limitations
  - Assess results to see if they comply with *specifications*
  - Provides documentation of system performance
  - Results of commissioning tests used later for QC tests

Commissioning

- IAEA TRS-430 provides sample tests
  - System set-up/machine configuration
  - Patient anatomical representation
  - External beam commissioning
  - Brachytherapy commissioning
  - Plan evaluation tools
  - Plan output and data transfer
  - Overall clinical tests


IAEA-TECDOC-1583

Commissioning of Radiotherapy Treatment Planning Systems: Testing for Typical External Beam Treatment Techniques

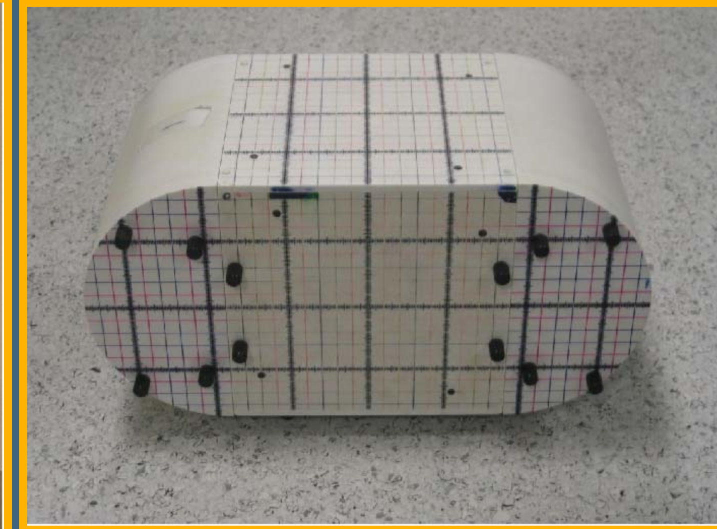
Report of the Coordinated Research Project (CRP) on Development of Procedures for Quality Assurance of Dosimetry Calculations in Radiotherapy

IAEA
International Atomic Energy Agency

January 2008

Phantoms Assessed by IAEA

Gammex RMI



Euromechanics Medical GmbH

Standard Imaging Inc.

CIRS Inc.

Modus Medical Devices Inc.

Other Phantoms

- 3-D & IMRT QA

Med-Tec

MLC Phantom

AAPM TG 66, 2003

Modus Medical Devices Inc

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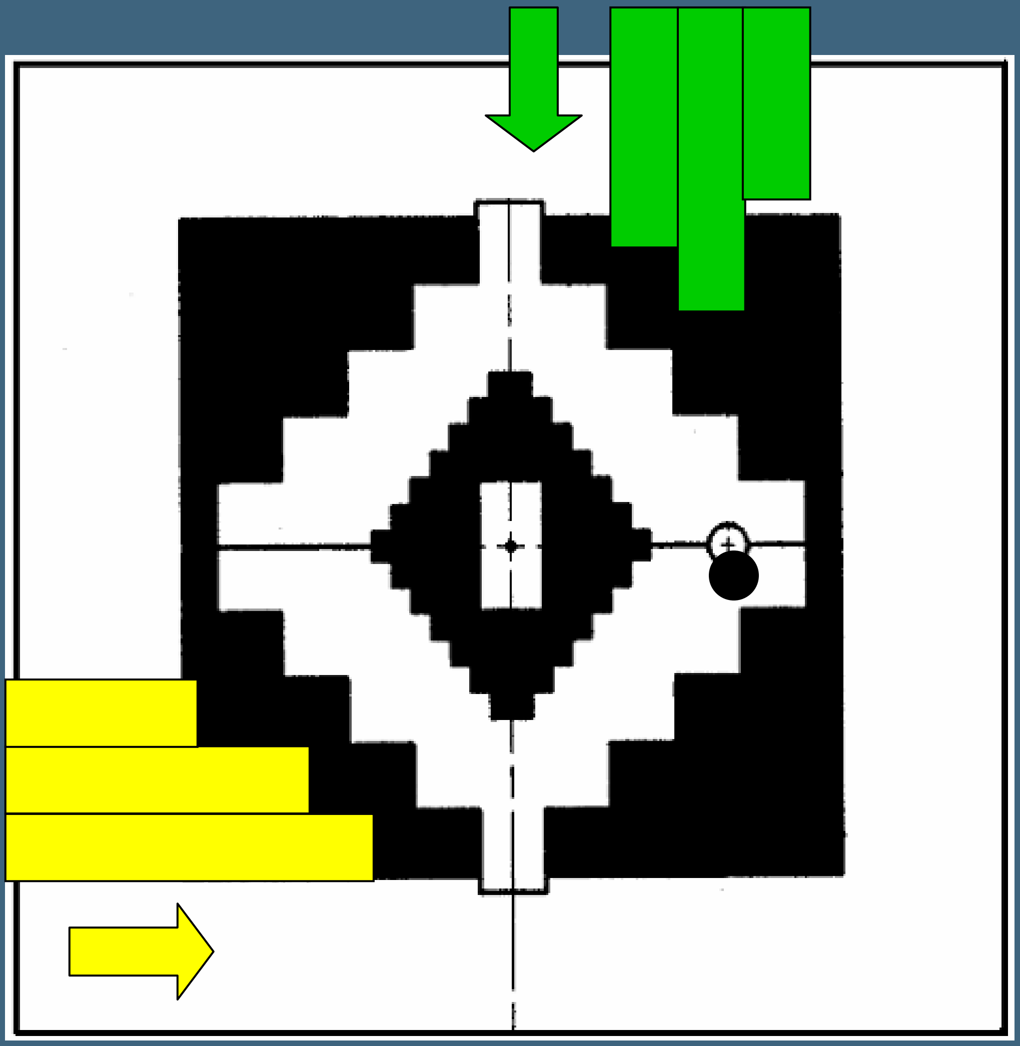
MLC Phantom

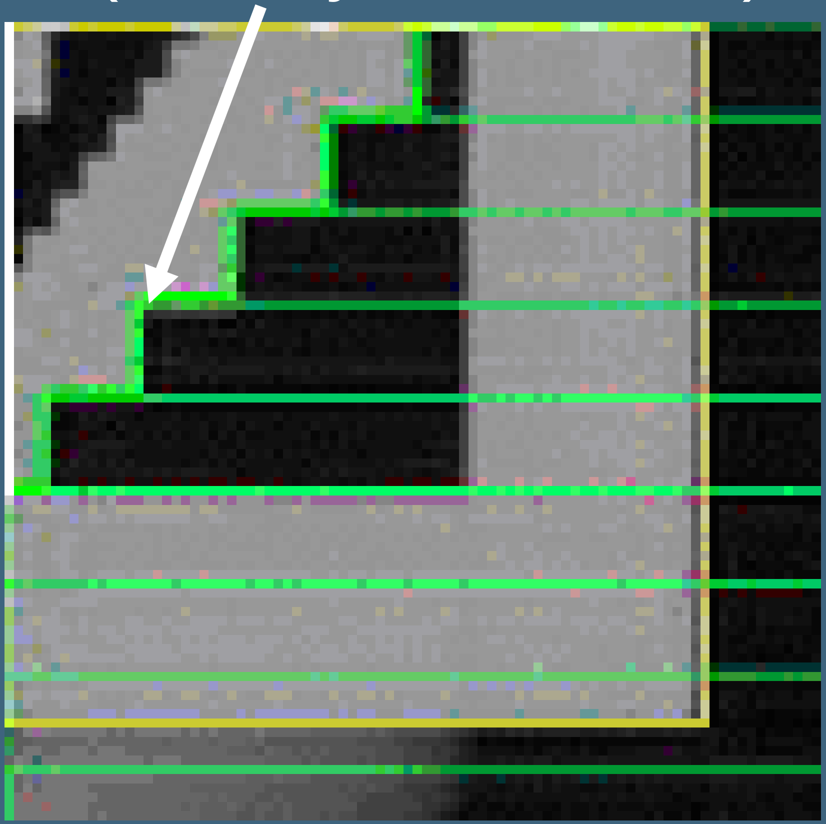


- Varian 52, 80 and 120 Leaf MLCs
- Elekta
- Radionics micro-MLC

- Siemens
- Varian 120 Leaf
- Brainlab micro-MLC

Multi-Observer Test

Does leaf end align with phantom geometry (air/acrylic interface)?



- Errors ≥ 2 mm, identified 100% of the time
- 1 mm errors identified 80% of the time

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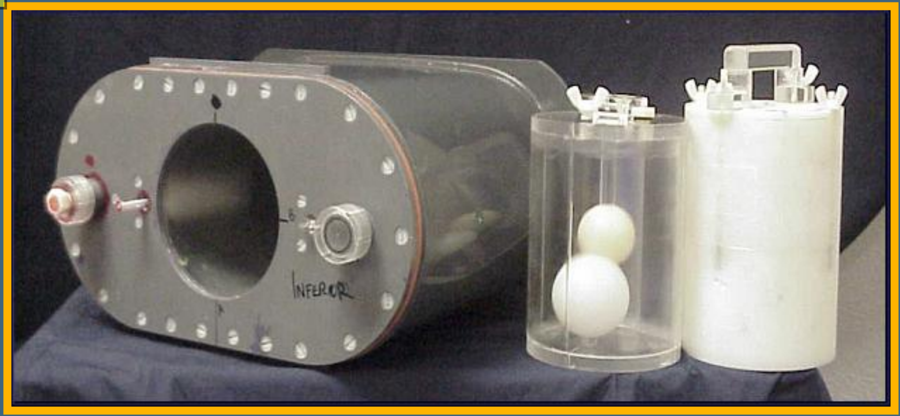
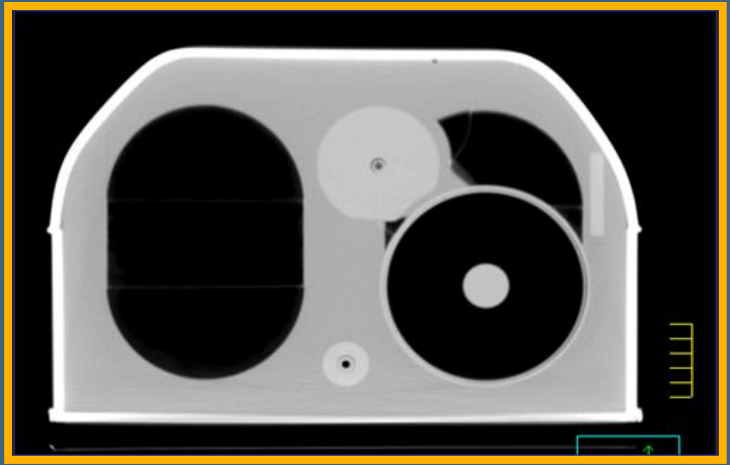
RPC Phantoms

- Geoff Ibbott…

RPC Phantoms



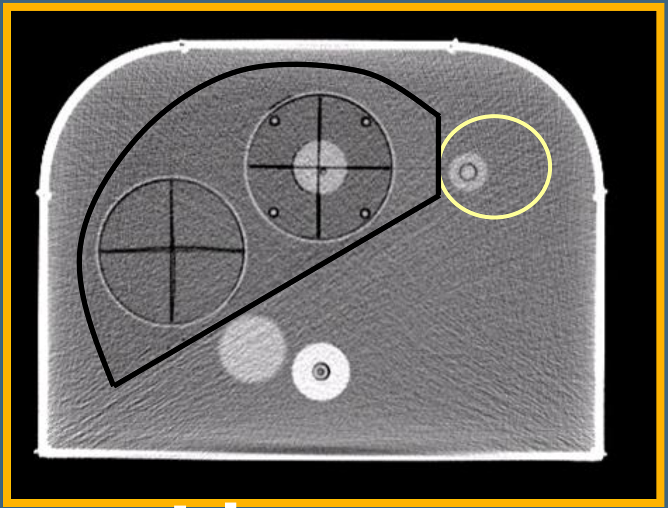
Pelvis (10)



Thorax (15)

H&N IMRT (31)

SRS Head (4)



Liver (2)

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IMRT H&N phantom results

- 558 irradiations were analyzed
- 425 irradiations passed the criteria
  - 70+ institutions irradiated multiple times
- 133 irradiations did not pass the criteria
- 377 institutions are represented

Only 76% of institutions passed the criteria on the first irradiation.

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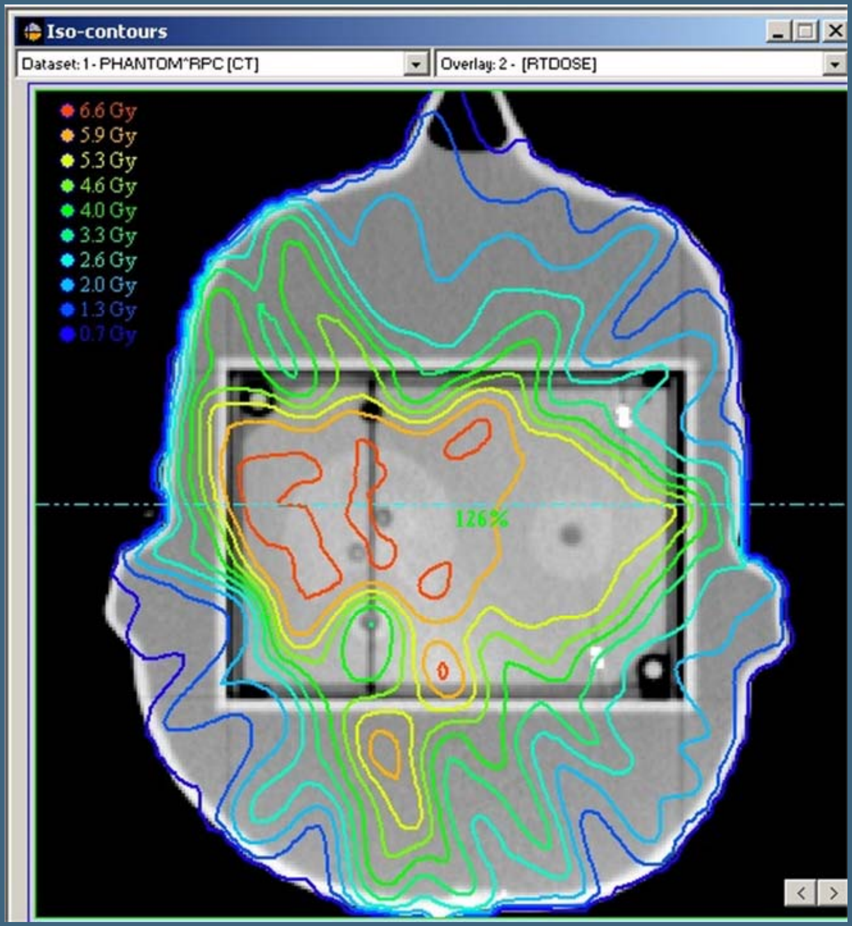
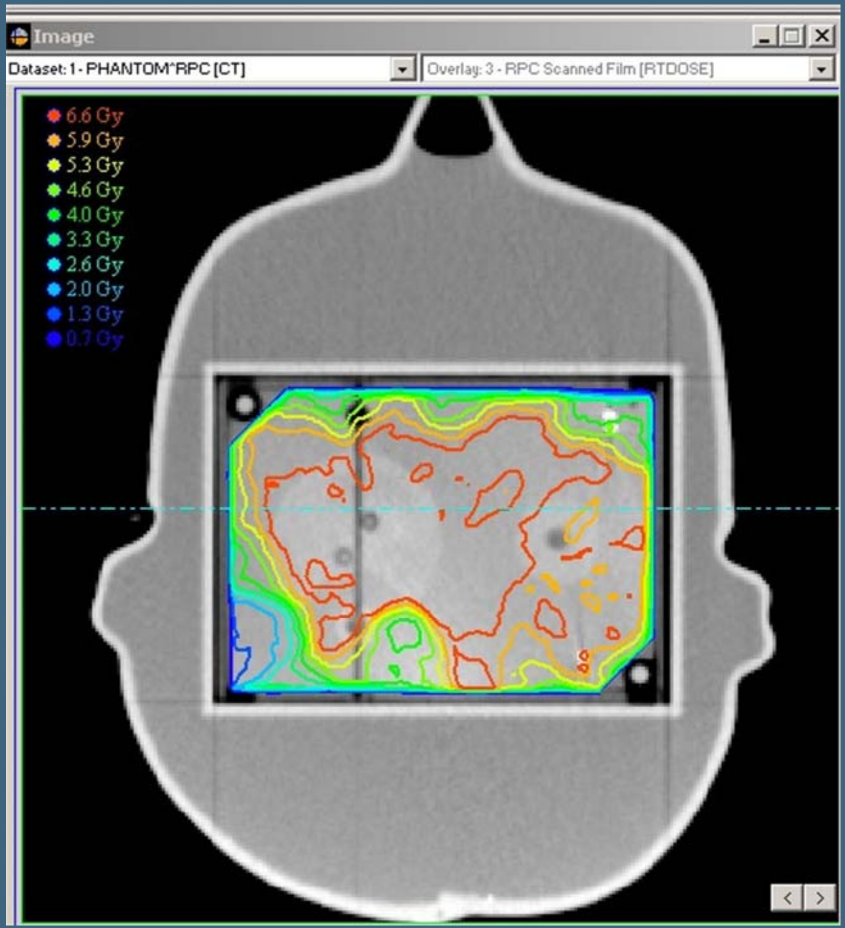
Examples of Failures





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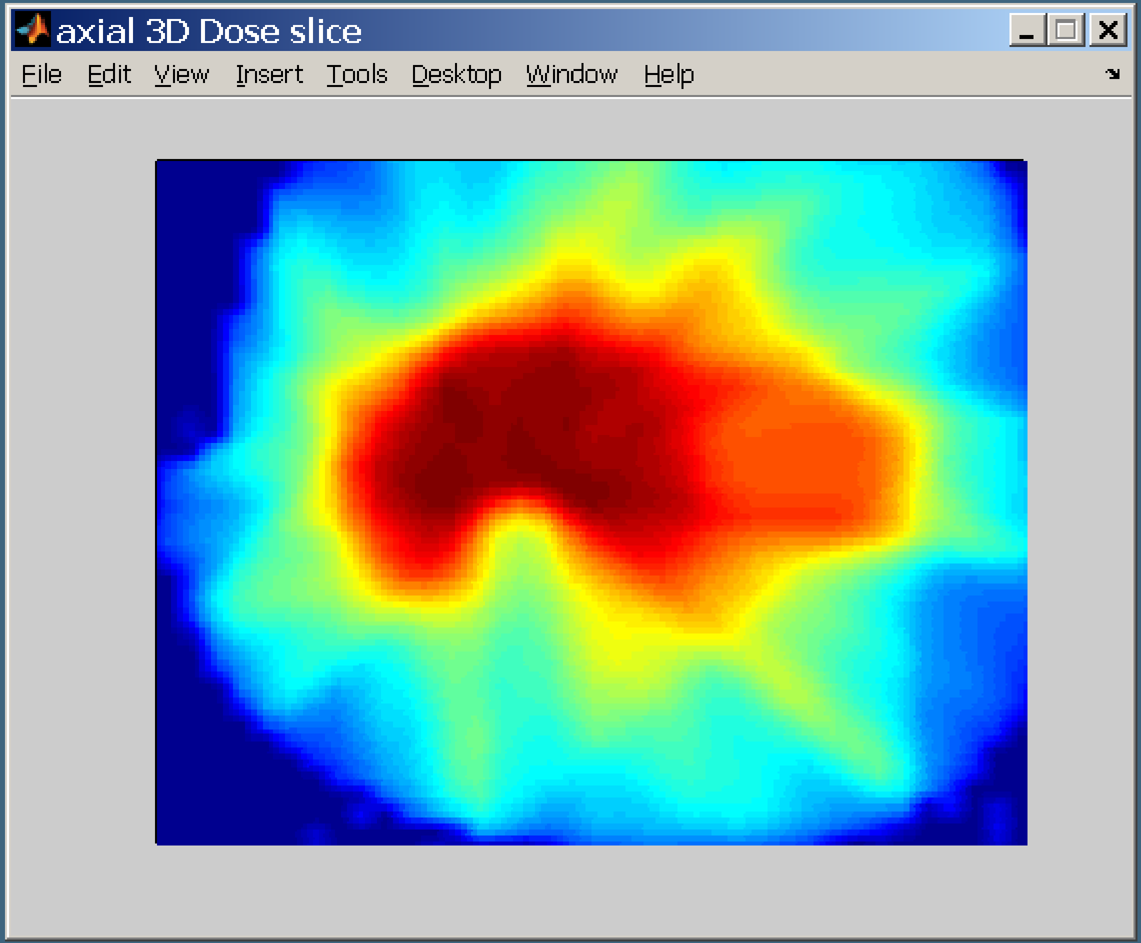
Comparison: Planned vs. Delivered Distribution



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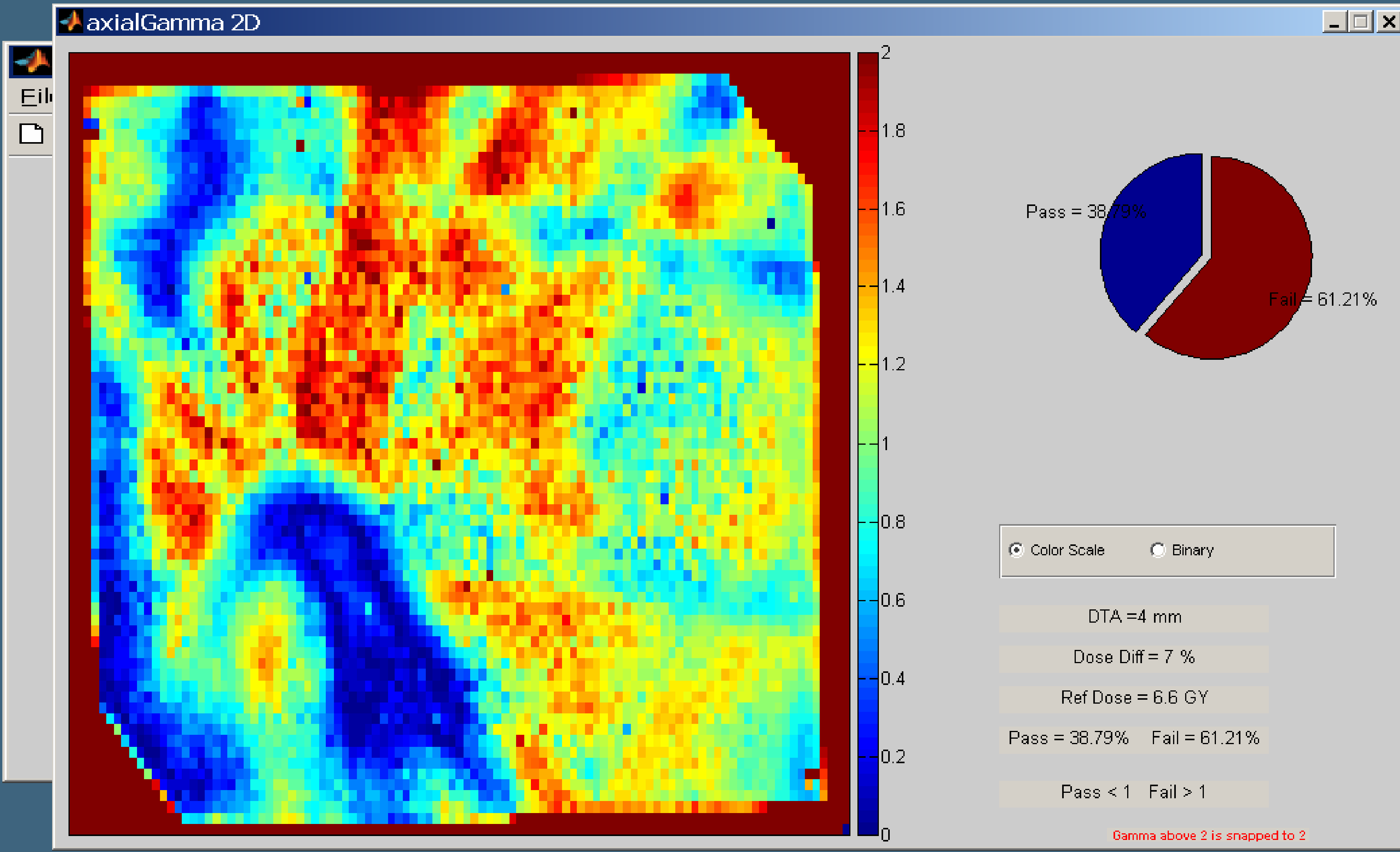
Comparison: Planned vs. Delivered Distribution



Explanations for Failures

Explanation	Minimum # of occurrences
Incorrect output factors in TPS	1
Incorrect PDD in TPS	1
IMRT plan that exceeds accel capabilities	3
Software error	1
Inadequacies in beam modeling at leaf ends (Cadman, et al; PMB 2002)	14
QA technique	3
Errors in couch indexing with Peacock system	3
Equipment performance	2
Setup errors	7

Lung Phantom Irradiations

TPS	Dose Calc. Algor correction on	Number of irradiations	D_{hetero}/D_{homo}
Precise v 2.01	Scatter Integ. Clarkson Type	2	1.19 ± 2.6%
BrainLab	Clarkson & Pencil Beam	5	1.22 ± 2.2%
Eclipse	Pencil Beam	5	1.18 ± 4.3%
Ergo	3D Convolution Pencil Beam	5	1.19 ± 0.1%
Render plan	Change in primary attenuation	1	1.20
Pinnacle v 6.2, 6.4, 7.0g, 7.4f	Adaptive Convolve	10	1.13 ± 2.1%
XiO	Superposition/ Convolution	5	1.11 ± 2.3%
	Total	33	

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TLD Dose vs. Hetero Corrected Plan

TPS	Dose Calc. Algor correction on	Number of irradiations	D_{TLD}/D_{hetero}
Precise v 2.01	Scatter Integ. Clarkson Type	2	0.99 ± 3.1%
BrainLab	Clarkson & Pencil Beam	5	0.96 ± 2.4%
Eclipse	Pencil Beam	5	0.96 ± 1.8%
Ergo	3D Convolution Pencil Beam	2	0.98 ± 3.2%
Render plan	Change in primary attenuation	1	0.92
Pinnacle v 6.2, 6.4, 7.0g, 7.4f	Adaptative Convolve	10	0.99 ± 2.1%
XiO	Superposition/ Convolution	5	0.96 ± 2.0%
	Total	33	

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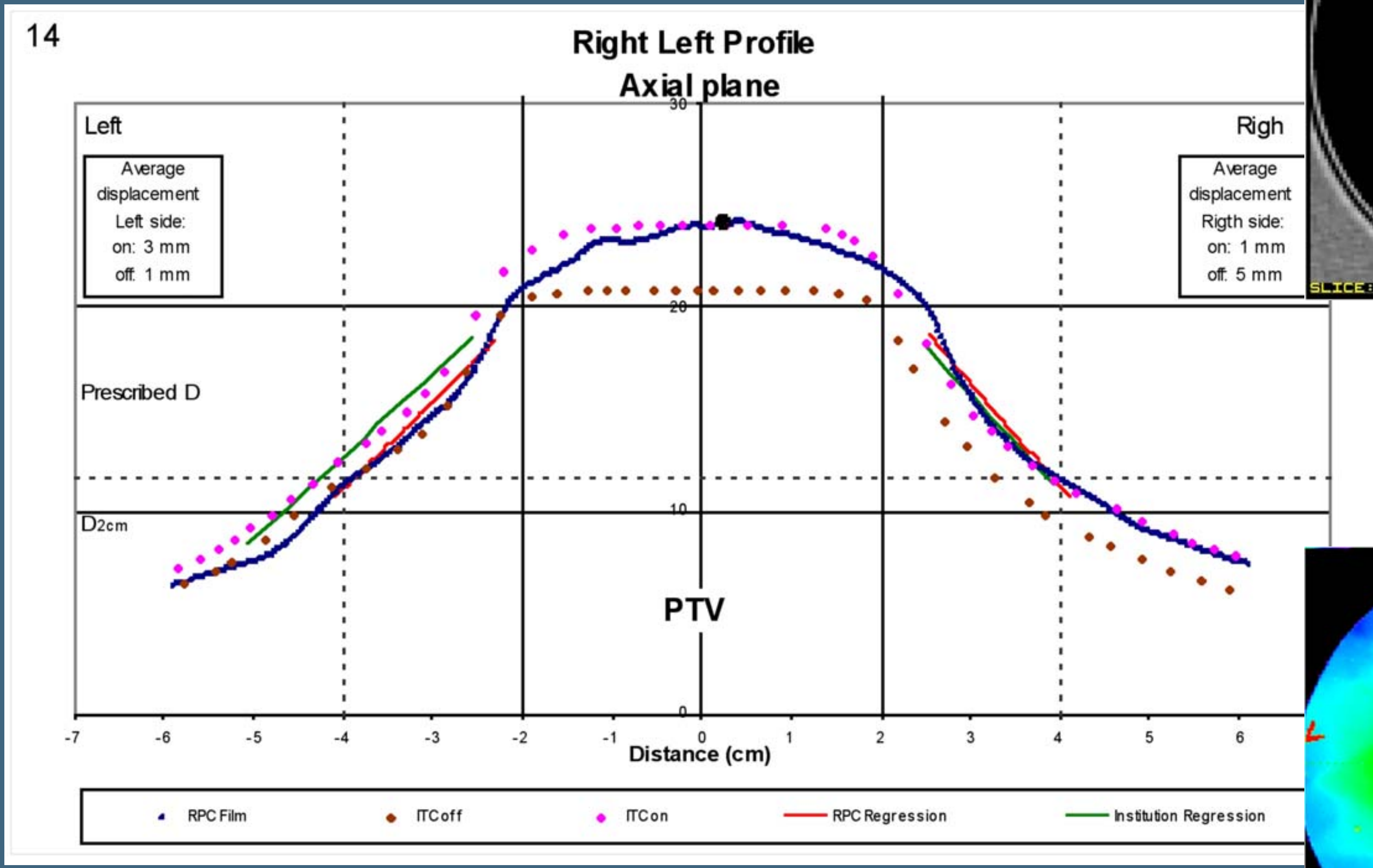
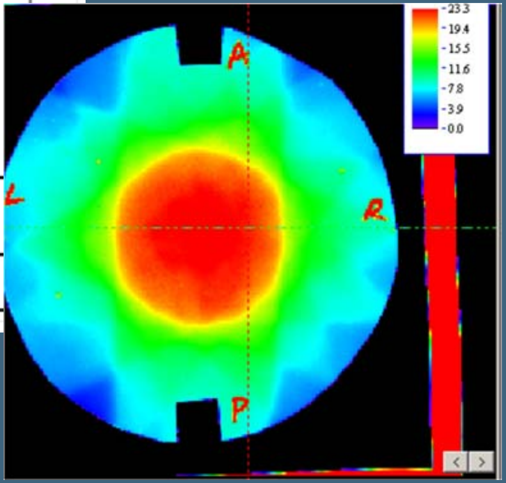
Convolution R-L Profile





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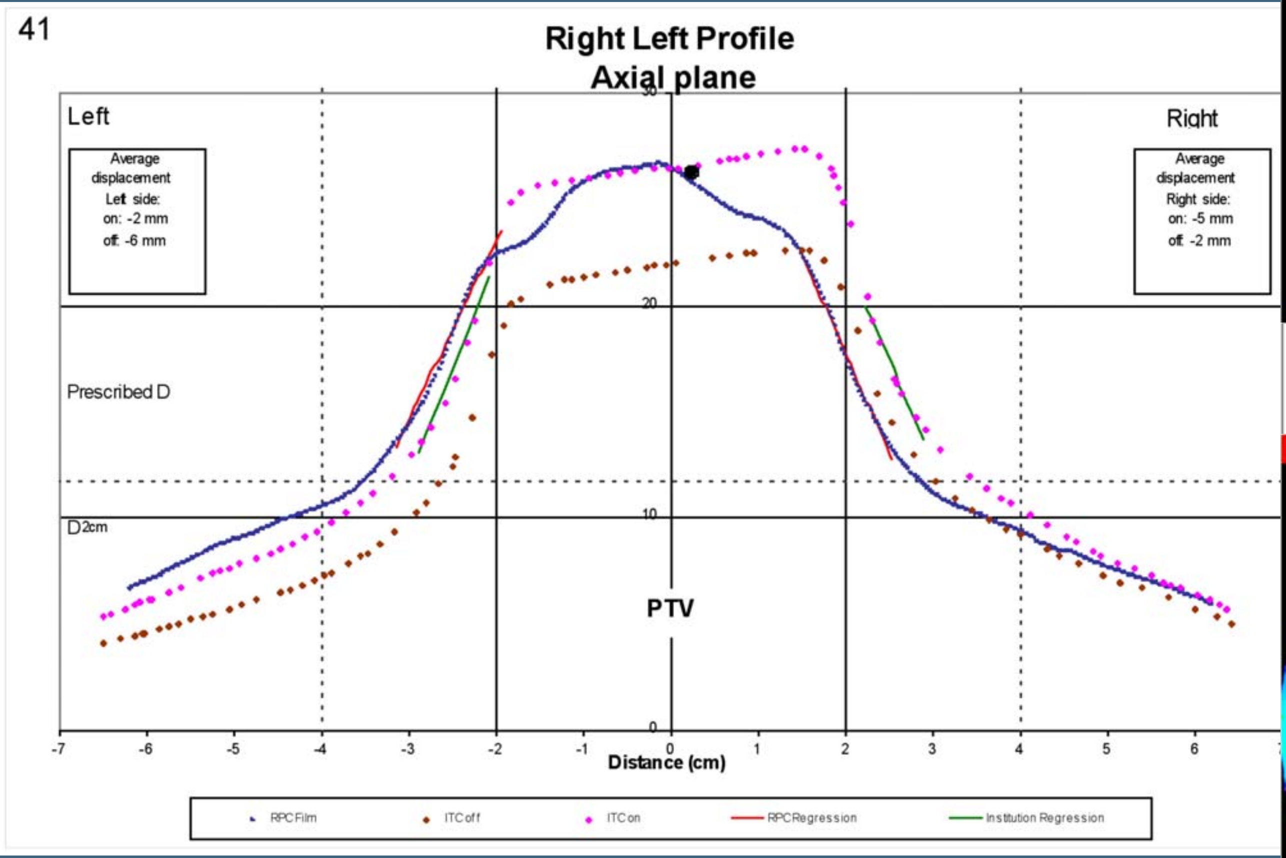
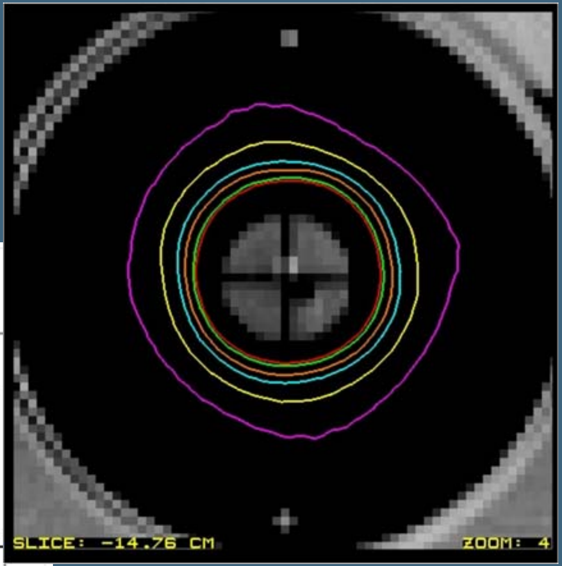
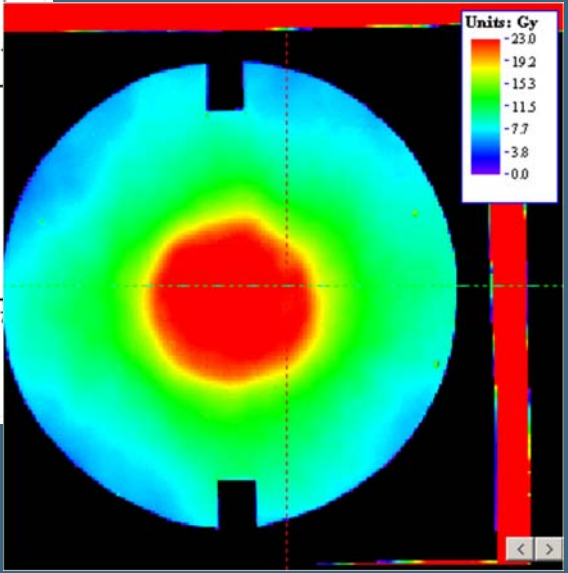
Pencil-Beam Profile







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RC-122 RSNA

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Errors, Inconsistencies, and Misunderstandings Discovered Through Credentialing

- RTPS used incorrect grid size, displayed isodoses in error
- RTPS truncated dose value; isodose incorrect
- Errors applying NIST 1999 correction
- Misunderstandings about TG-43
- Misunderstanding of protocol, volumes
- Poor brachytherapy technique

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Quality Control

PS = Patient specific, W = Weekly, M =Monthly,
Q = Quarterly, A = Annually,
U = After software or hardware update

Subject	Test	PS	W	M	Q	A	U
Hardware							
CPU	QC Test 1			*			*
Digitizer	QC Test 2		*[1]	*[2]			*
Plotter	QC Test 3				*		*
Backup recovery	QC Test 4				*		*
Anatomical information							
CT (or other) scan transfer	QC Test 5	*					*
CT geometry and density check	QC Test 6				*		*
Patient anatomy	QC Test 7	*					*
External beam software (photons and electrons)							
Revalidation (including MU)	QC Test 8	*				*	*
Monitor unit	QC Test 9	*					
Plan details	QC Test 10	*		*			
Electronic plan transfer	QC Test 11	*		*		*	*
Brachytherapy							
Revalidation	QC Test 12					*	*
Plan details	QC Test 13	*					
Independent dose/time check	QC Test 14	*					
Electronic plan transfer	QC Test 15	*		*		*	*
TPS software recommissioning	Section 10.3.2.4						

[1] Sonic digitizer, [2] Electromagnetic digitizer

IAEA TRS-430 Table 61

QA Administration

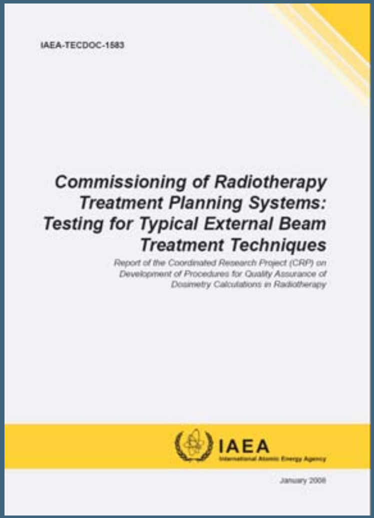
- One “qualified medical physicist” responsible
- Documentation of QA process
- Record results
- Clear channels of communication re:
  - Software changes on RTPS
  - New/altered data files
  - CT imager software/hardware changes
  - Machine output changes

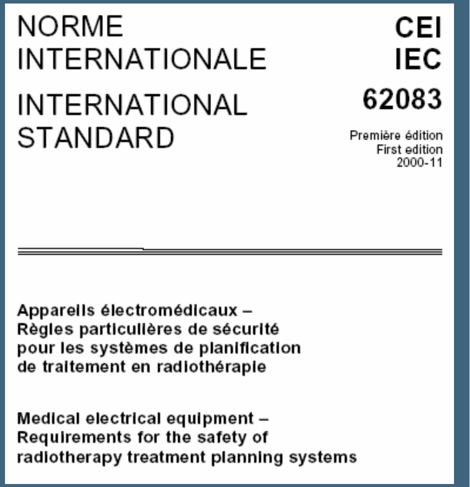
Issues Not Addressed in Current Reports

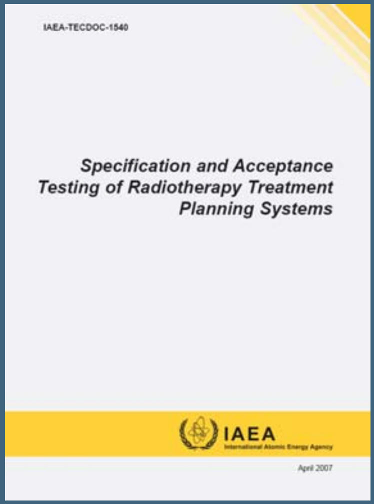
- Issues related to IMRT, gated therapy, image guidance (tomotherapy, cone beam CT), daily dose reconstruction
- TG 100 – Methods for Evaluating QA Needs in Radiation Therapy
  - Problems with the “old approach” to QA
  - Recommended risk-assessment approach
    - Systemic approach to processes rather than “human failure”
    - Failure modes and effects analysis (FMEA)
    - Identification and prioritization of failure pathways
    - Determination of achievable QM program based on risk analysis
  - Examples of application to IMRT, HDR brachytherapy
  - Suggestions for applying FMEA in radiation therapy

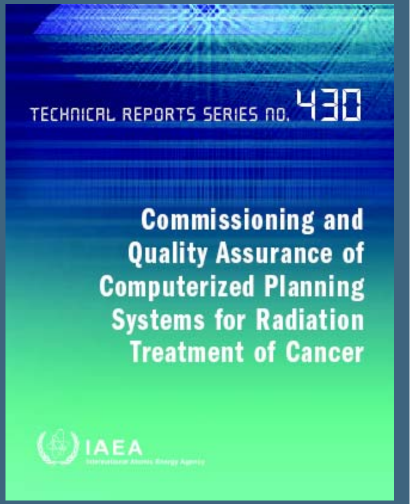
Summary

- Formal QC program includes:
  - User training
  - Well-defined acceptance tests
  - Well-defined (re)commissioning tests
  - Well-defined repeatability checks
  - Appropriate actions as needed
  - Documentation of results
  - Patient specific QC
- Process QA
  - Incident/error rate
  - Number of replans
  - Timeliness
  - Physician satisfaction





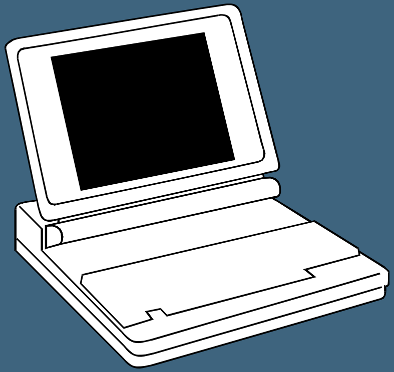




RTPS QA - Key Issues

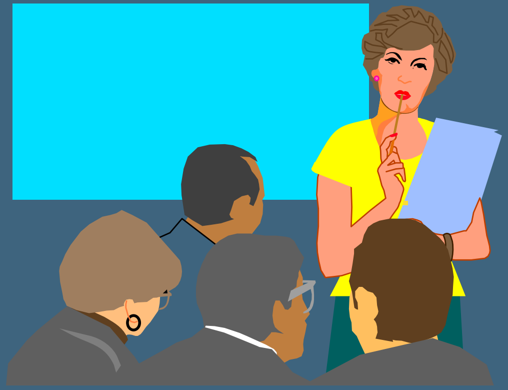
Education

Documentation



Verification

Communication



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