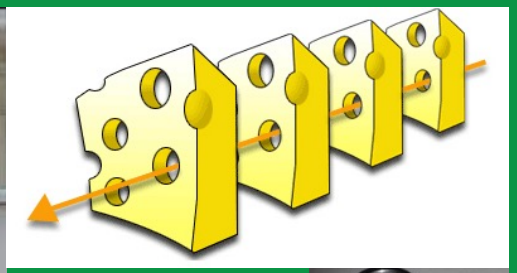
SERVIZIO SANITARIO REGIONALE
EMILIA-ROMAGNA
Azienda Ospedaliero - Universitaria di Modena

The Abdus Salam International Centre for Theoretical Physics

QUALITY ASSURANCE PROGRAMME



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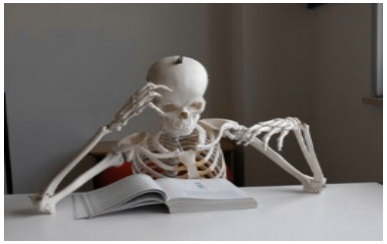
QUALITY ASSURANCE (QA)

Quality assurance (QA)

- *Quality assurance*
- *Quality system*
- *Quality standards*
- *Quality controls*

Quality assurance in Radiotherapy

- *Guidelines*
- *Medical Device QA*
- *Non-Medical Device QA*
- *Patients QA*
- *Present and future of RT QC*
- *Tests: frequency and tolerances*
- *Tools and other QA programs*



Today I will not provide specific QA methods and tests…
You should find (define) the tests and methods adequate and appropriate for your center, experiences, technologies and available tools
…look at the problems and guidelines!

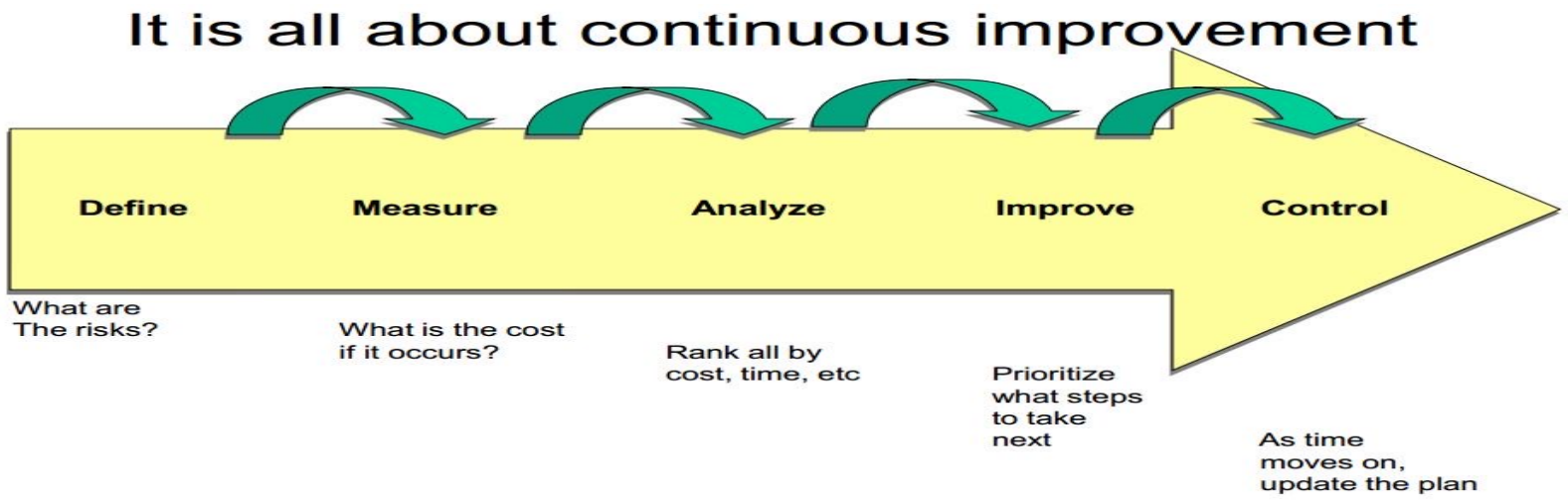
IDENTIFY OR PREVENT SOURCE OF ERRORS?

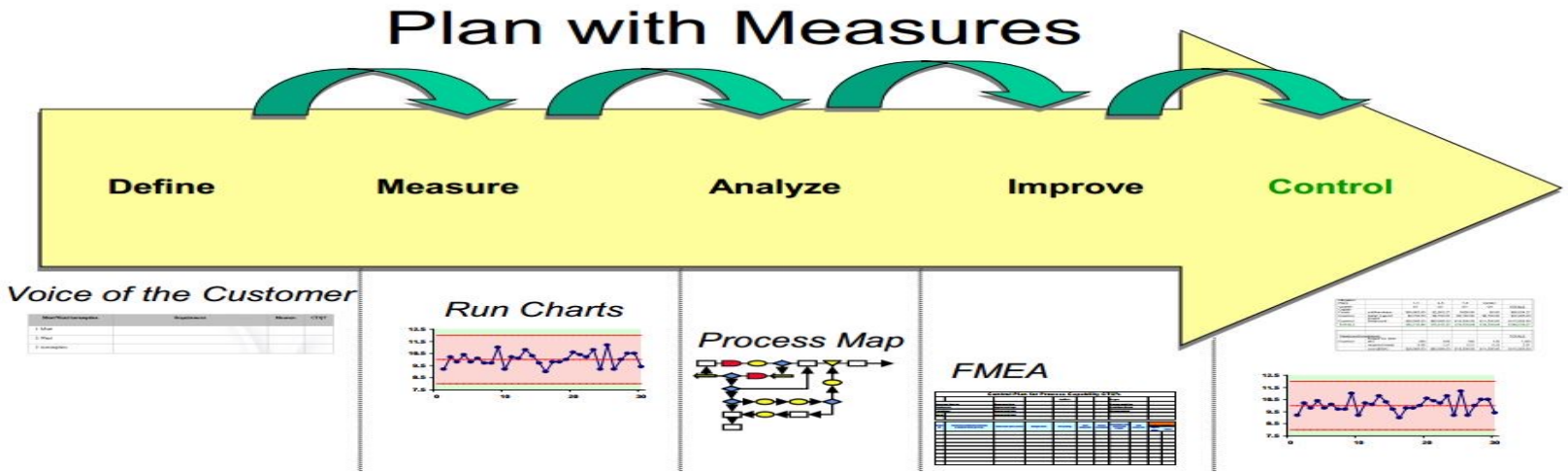
Look for:
Small or big errors?
Rare or frequent errors?
Random or systematic errors?
Unpredictable or newly errors?

Matteo 7:3 : "Why do you look at the speck of dust in your brother's eye, but fail to notice the log in your own eye?"

To be accurate once a year (Annual QA) or to be adequate everyday (Daily QA)?:

Simplify theory and QA Programme (i.e. Six Sigma)

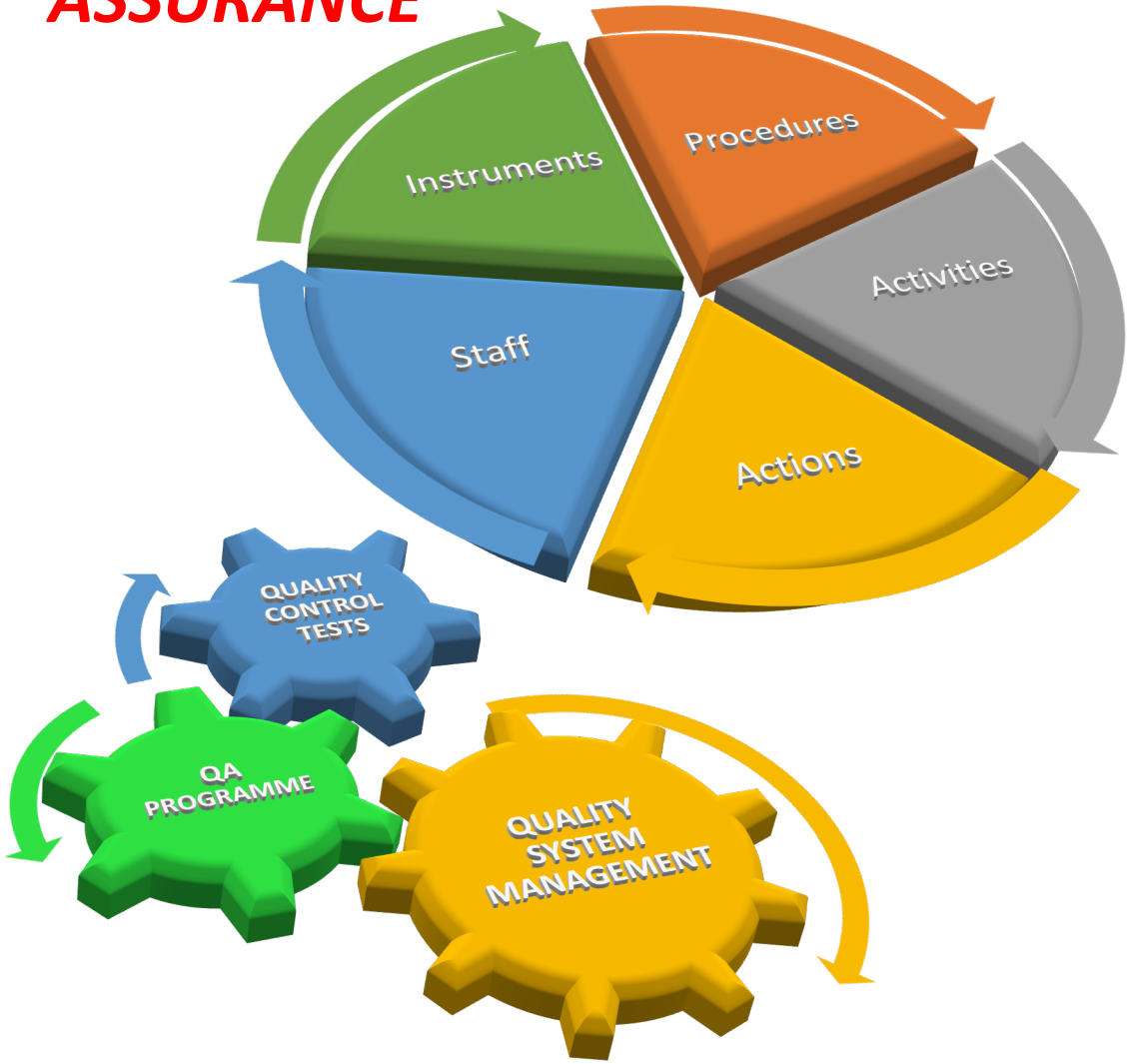


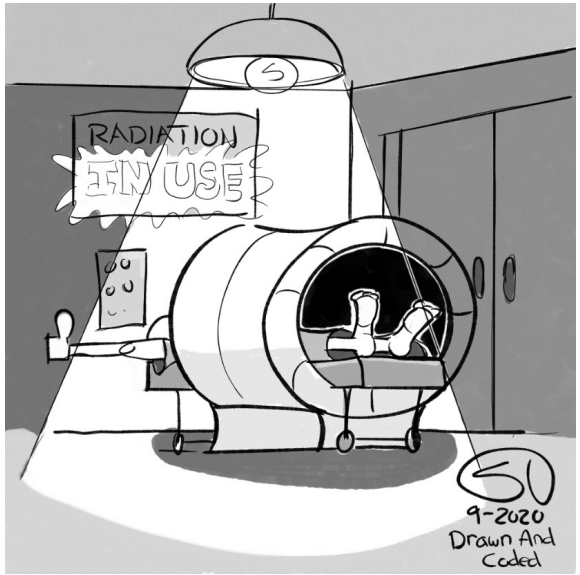


QUALITY ASSURANCE (QA)

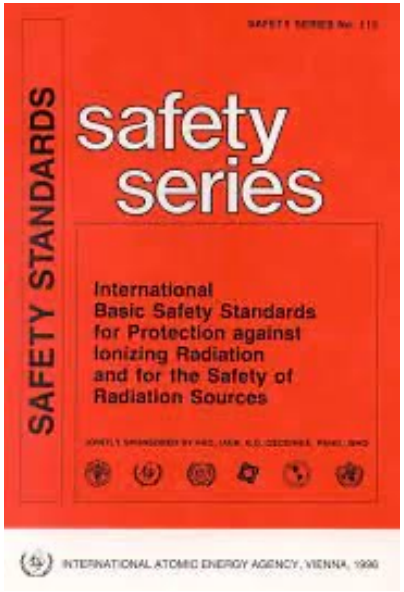
QUALITY ASSURANCE

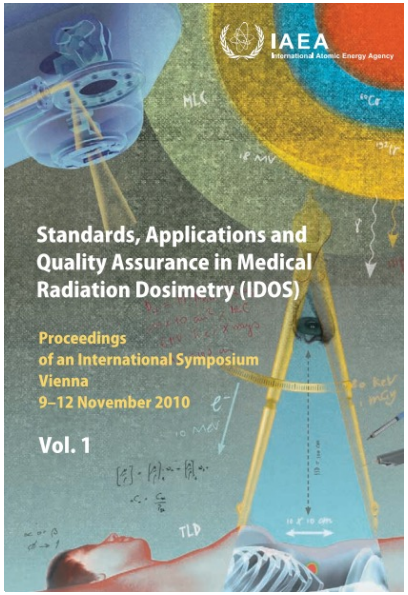
All the planned and systematic actions necessary to provide adequate confidence that a product or service will satisfy the given requirements for quality. (Prof. Golam Abu Zakaria)

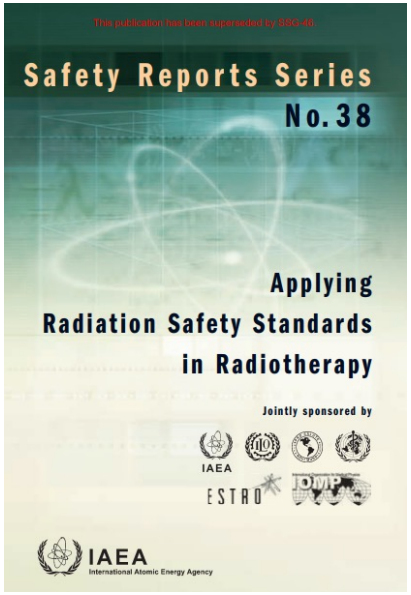


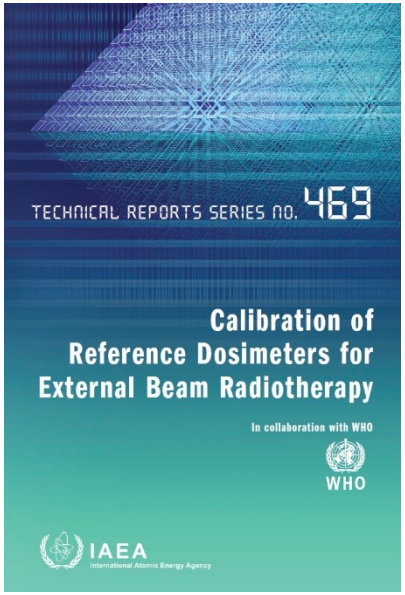


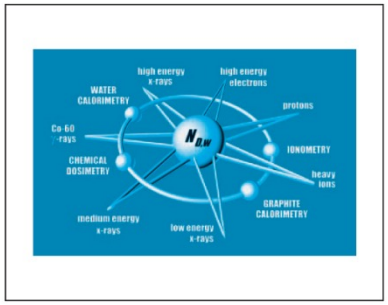
QUALITY ASSURANCE (QA) – Sample Guidelines











TECHNICAL REPORTS SERIES No. 398

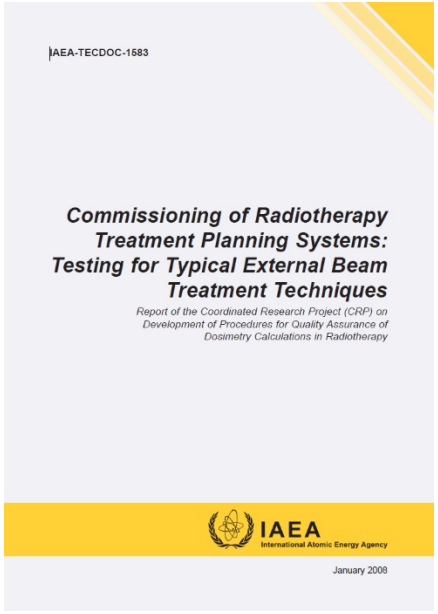
Absorbed Dose Determination in External Beam Radiotherapy

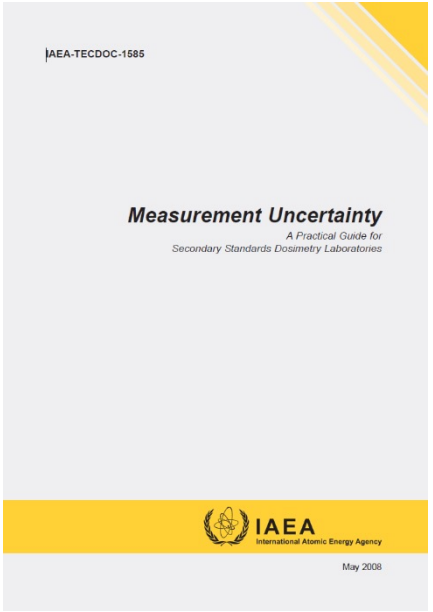
An International Code of Practice for Dosimetry Based on Standards of Absorbed Dose to Water

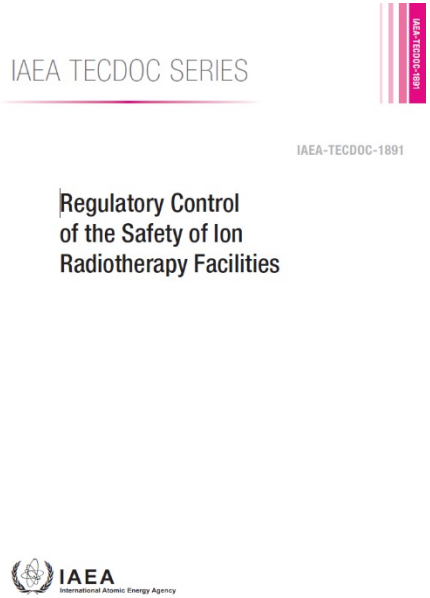
Sponsored by the IAEA, WHO, PAHO and ESTRO

ESTRO

INTERNATIONAL ATOMIC ENERGY AGENCY, VIENNA, 2000







QUALITY ASSURANCE (QA) – Sample Guidelines

IAEA International Atomic Energy Agency

Press centre Employment Contact

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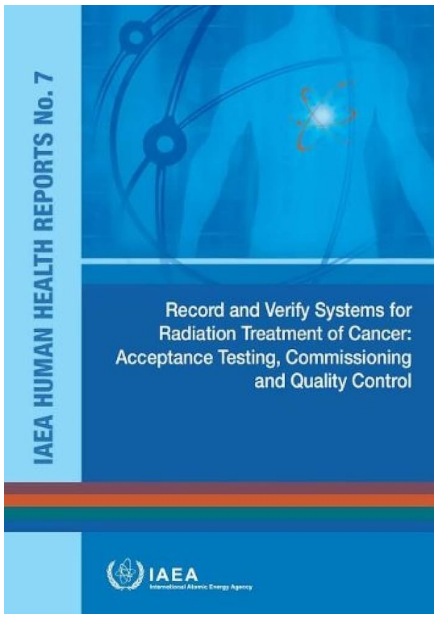
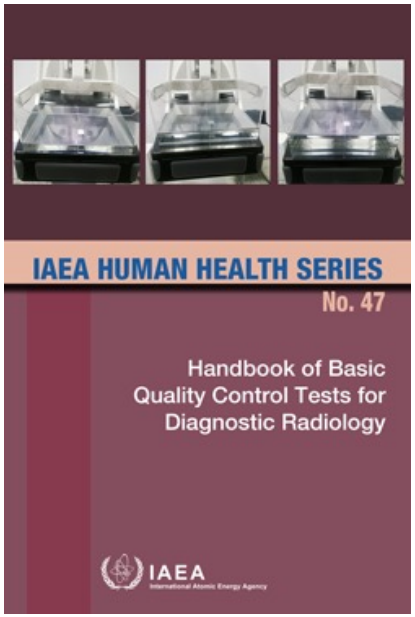
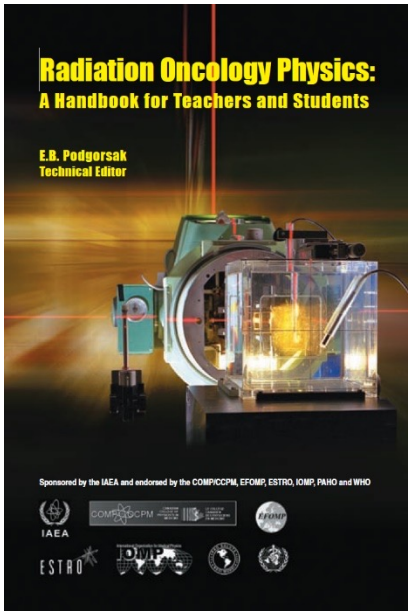
Publications advanced search

IAEA scientific and technical publications can be searched by multiple parameters: year of publication, topic and type. Use the facets to input your search criteria or the text field to search by title, keyword, ISBN, ISSN or series number.







Please, refer to recognized and registered international agencies and associations, not to occasional websites

NO NEED TO INVENT ANYTHING: THE GUIDELINES ARE AVAILABLE!

Safety Reports Series

IAEA

ESTRO

aifm

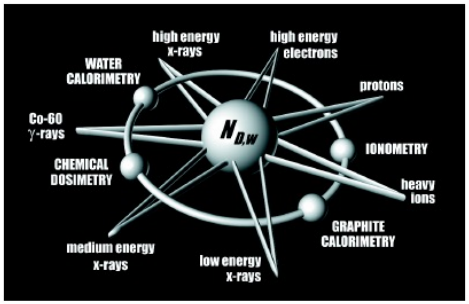
World Health Organization

BIR

IPEM

IAEA TRS-398

Absorbed Dose Determination in External Beam Radiotherapy: An International Code of Practice for Dosimetry based on Standards of Absorbed Dose to Water



Pedro Andreo, Dosimetry and Medical Radiation Physics Section, IAEA
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Klaus Hohlfeld, Physikalisch-Technische Bundesanstalt (PTB), Braunschweig, Germany
M Saiful Huq, Thomas Jefferson University, Philadelphia, USA
Tatsuaki Kanai, National Institute of Radiological Sciences (NIRS), Chiba, Japan
Fedele Laitano, Ente per le Nuove Tecnologie L'Energia e L'Ambiente (ENEA), Rome, Italy
Vere Smyth, National Radiation Laboratory (NRL), Christchurch, New Zealand
Stefaan Vynckier, Catholic University of Louvain (UCL), Brussels, Belgium

PUBLISHED BY THE IAEA ON BEHALF OF IAEA, WHO, PAHO, AND ESTRO

INTERNATIONAL ATOMIC ENERGY AGENCY IAEA

Organize and Track the documentation

Possible definition (ISO Source):

A ***Quality Management System*** is a set of all connected and interdependent activities that influence the Quality of a product or service. Documents the processes, procedures and responsibilities for achieving quality policies and quality objectives.

The *Quality Management System* consists of:

- An organizational structure
- The processes
- Responsibilities
- The procedure
- Resources
- People who know what to do
- People who know how to do it
- People who have the means to do it
- People motivate to do it because they have a common goal

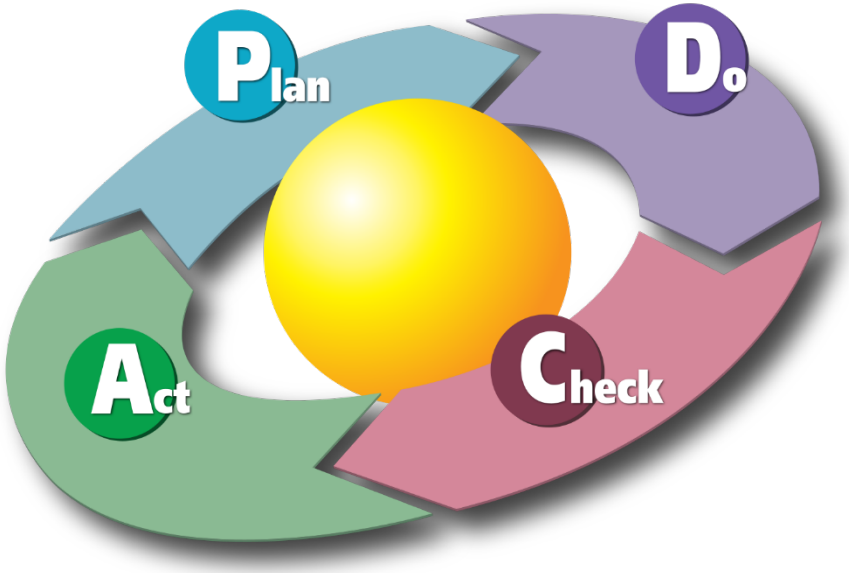
QA SYSTEMS AND STANDARD

It's not just paper and operating instructions

QA PROGRAMME
National or Local Regulatory, Quality System, Certification and Tools. (Examples)

Certification Office

PDCA Cycle (Deming Cycle)



Certification Office

National and Local Regulatory

E.g. Requirements in Italy and Emilia Romagna……..

n.332 del 13.12.2017 periodico (Parte Seconda)

Regione Emilia-Romagna

DELIBERAZIONE DELLA GIUNTA REGIONALE 4 DICEMBRE 2017, N. 1943

Approvazione requisiti generali e procedure per il rinnovo dell'accreditamento delle strutture sanitarie

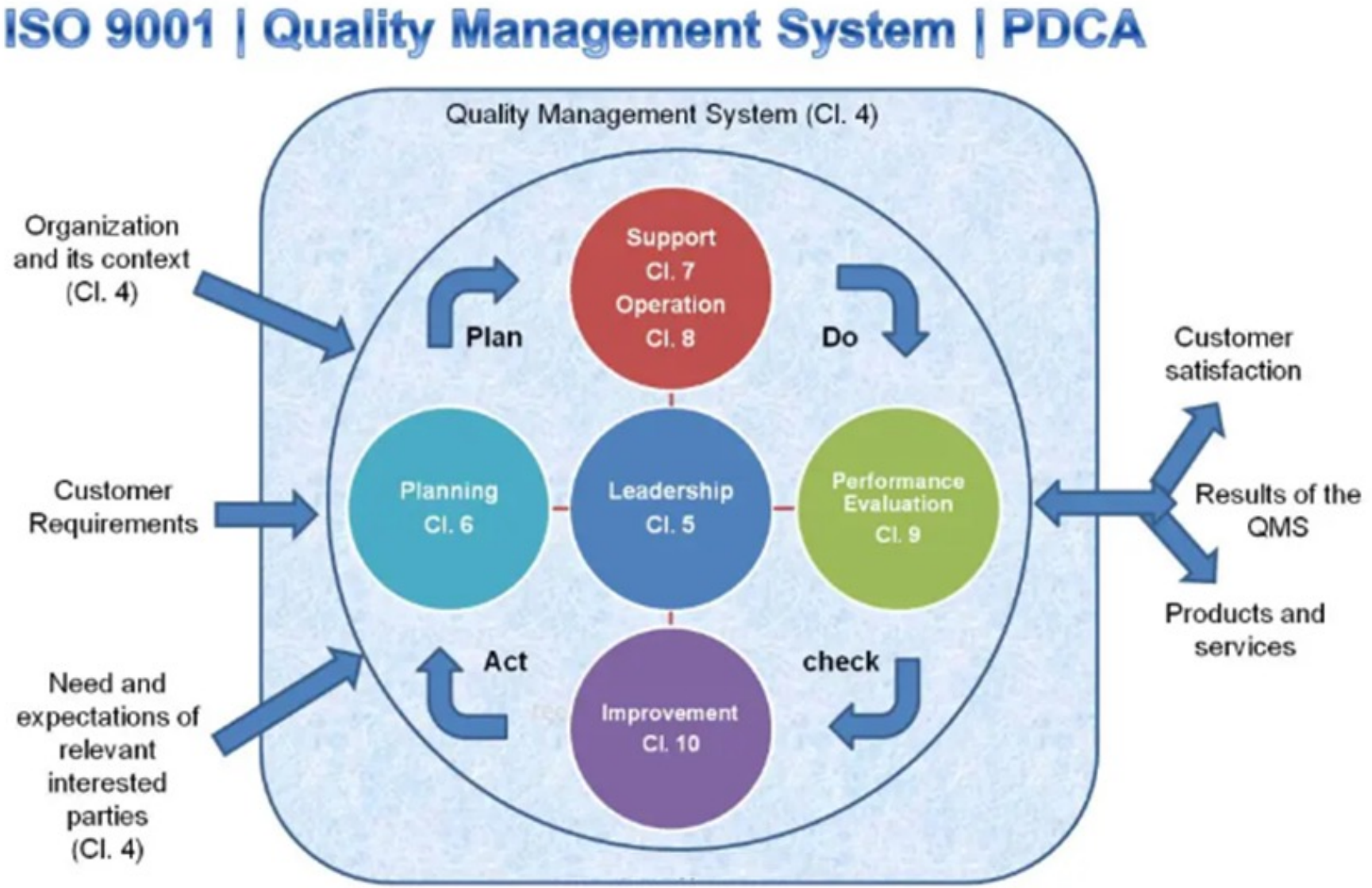
LA GIUNTA DELLA REGIONE EMILIA-ROMAGNA

Requisiti specifici Fisica sanitaria

Estratto dalla delibera Giunta regionale n. 327 del 23 febbraio 2004 "Applicazione della L.R. n. 34/98 in materia di autorizzazione e di accreditamento istituzionale delle strutture sanitarie e dei professionisti alla luce dell'evoluzione del quadro normativo nazionale. Revoca di precedenti provvedimenti"

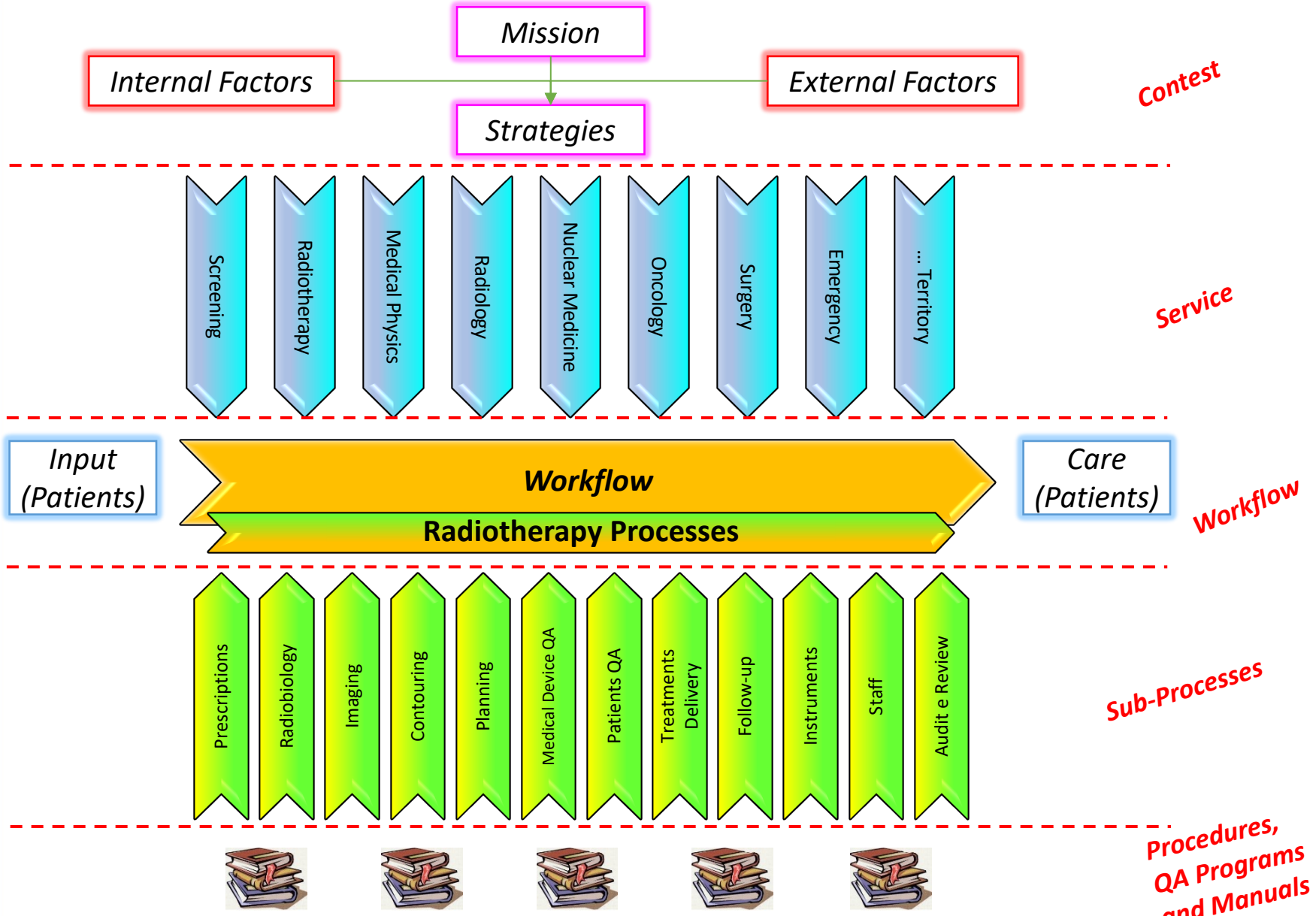
Requisiti specifici per l'accreditamento delle Strutture di fisica sanitaria

Example of an Organizational Model
(i.e. Medical & Health Physics Service for radiotherapy)



Source ISO 9001:2015

Workflow, Processes, Sub-processes and Procedures



Documentation tracking (example)

SERVIZIO SANITARIO REGIONALE EMILIA-ROMAGNA Azienda Ospedaliero-Universitaria di Modena	_____TITOLO_____	P_____ REV. Pag 1/n

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2.2. SCOPO..... 1
3. CAMPO DI APPLICAZIONE.....**1**
4. RESPONSABILITÀ.....**1**
5. INDICATORI APPLICABILI.....**1**
6. DOCUMENTI DI RIFERIMENTO.....**1**
7. DEFINIZIONI.....**1**
8. CONTENUTO.....**1**
8.1 GENERALITÀ..... 1
8.2 LOGIGRAMMA..... 1
8.2 NOTE..... 1
9. ALLEGATI.....**1**

Referente della procedura: ..... (UO di appartenenza.....)

Gruppo di Lavoro:
..... (UO di appartenenza.....)
..... (UO di appartenenza.....)
..... (UO di appartenenza.....)
..... (UO di appartenenza.....)

Lista di distribuzione:
UO .....
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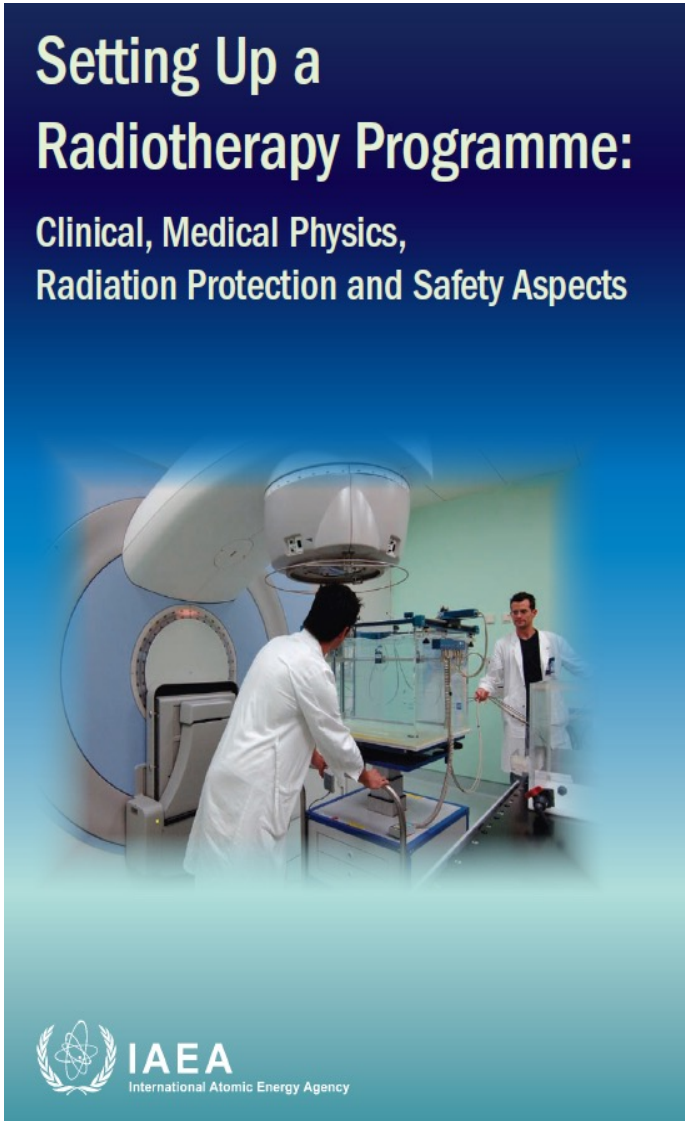
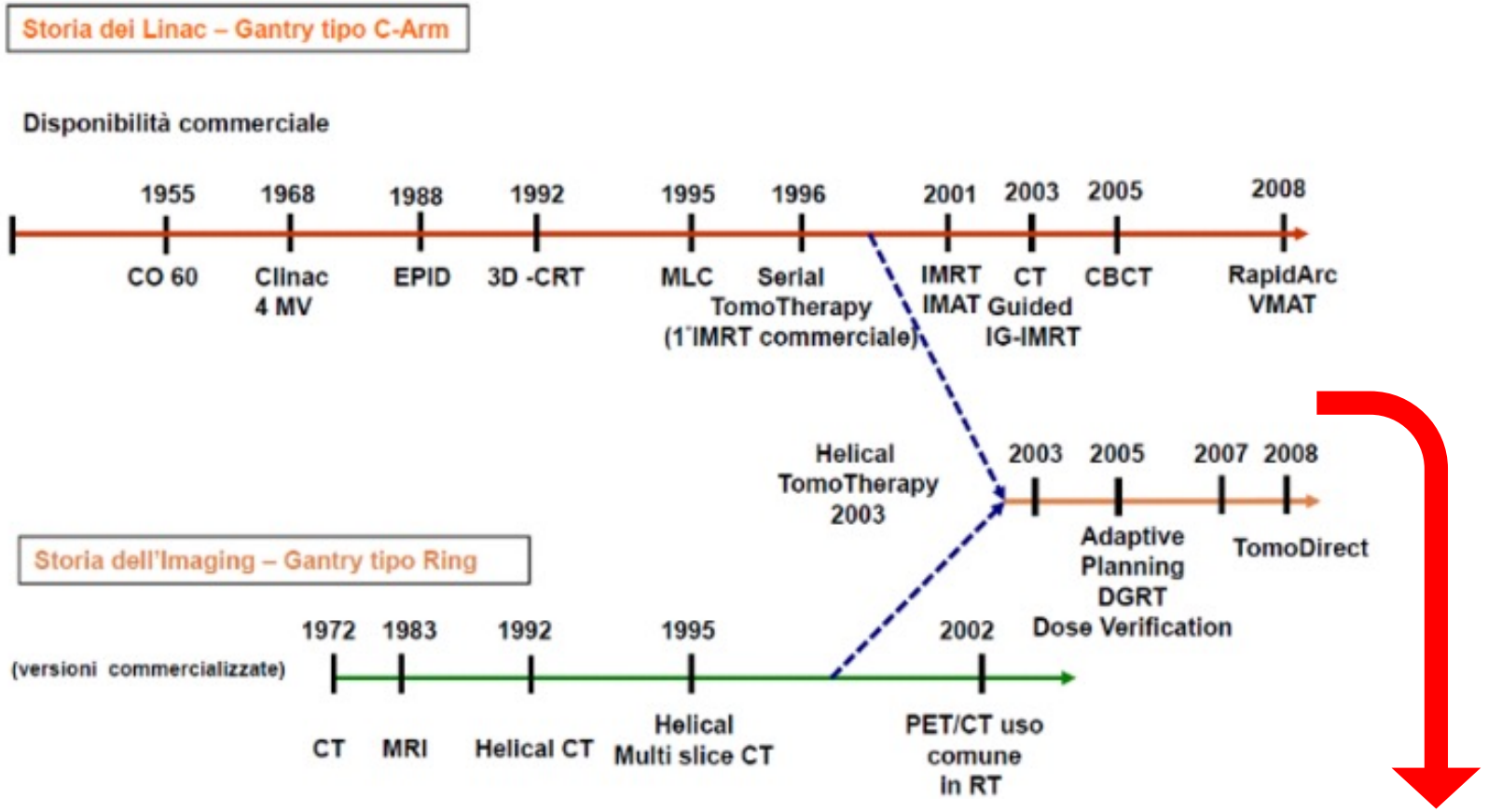
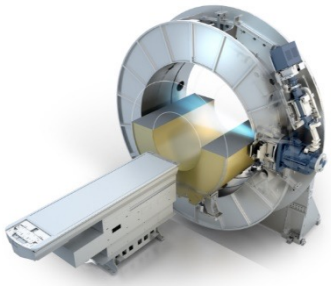
REDAZIONE			VERIFICA			APPROVAZIONE		
Data	Funzione	Visto	Data	Funzione	Visto	Data	Funzione	Visto

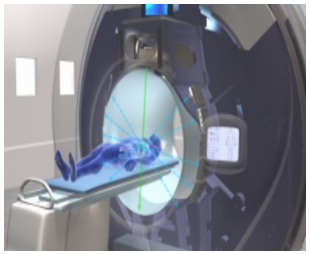
SETUP QA PROGRAMME AND DO IT!!



LINAC & IMAGING : EQUIPMENT'S EVOLUTION in RT



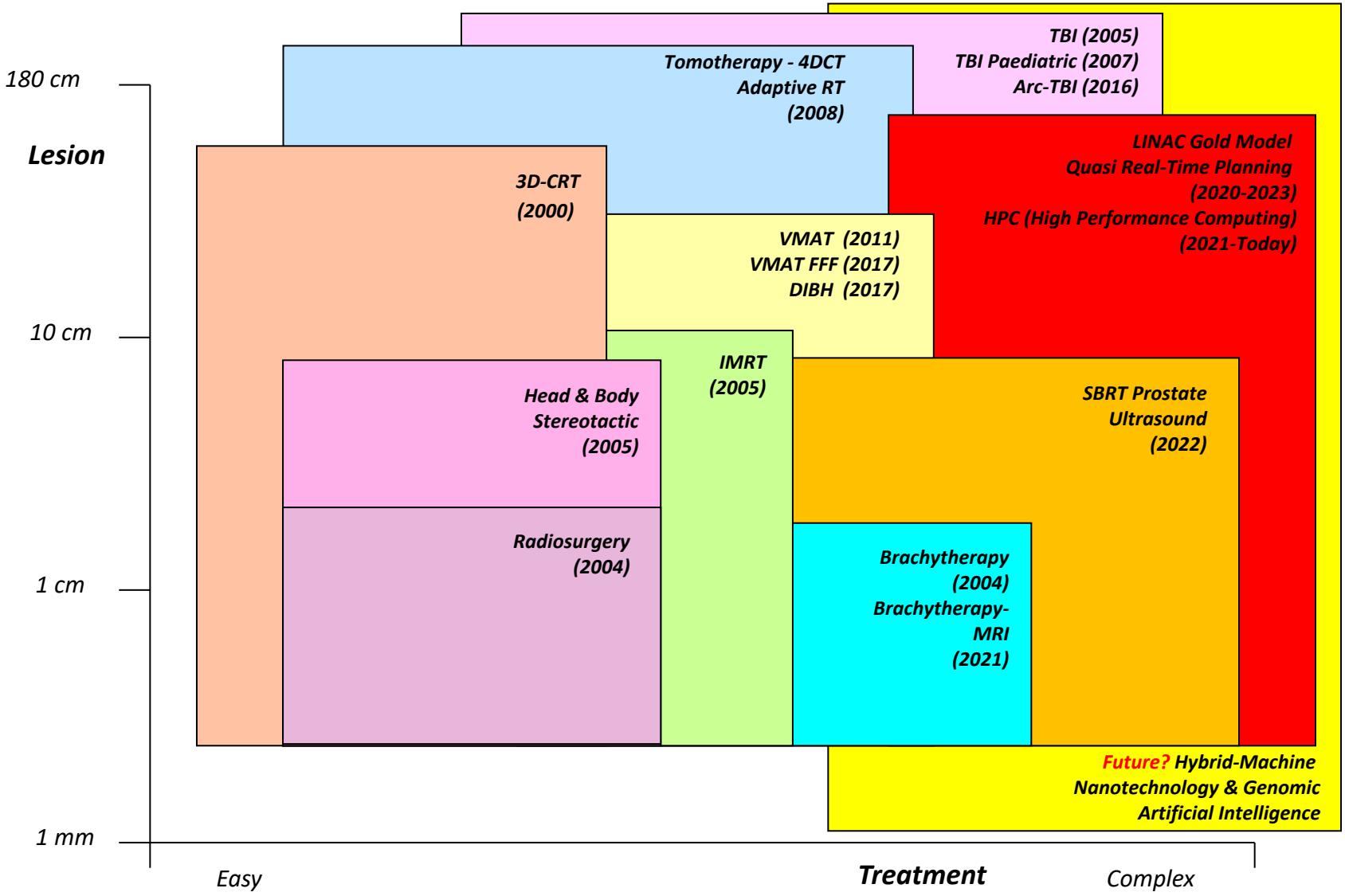




NEXT GENERATION

- ***LINAC MRI***
- ***LINAC PET***
- ***PROTON AND CARBON***
- ***……..THERAPY***

RADIOTHERAPY… ROADMAP



Radiotherapy Network & Facility

HIS | eChart COM.NET | Billing AURIGA | PACS/PACS-RT | REPOSITORY DIGITAL & LEGAL DATA | ARCHIVE/BACKUP | MOSAIQ

Hospital Network (Data Center)

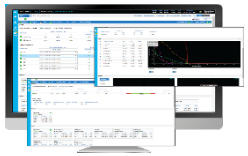
Interoperable Network

Radiotherapy Network and Facility

MR 1.5T Philips
MR 3.0T GE

Siemens Biograph 64 mCT

Toshiba Aquilion 16



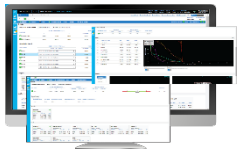
AI – HPC
Research

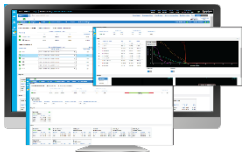
Monaco

Oncentra-Brachy

Raystation

MyQA &
PerFraction





Imaging

Planning and QA systems

Hub Hospital
Treatment Machine

(Remote site)
Hospital
Treatment Machine

Network and Imaging

HIS | eChart COM.NET | Billing AURIGA | PACS/PACS-RT | REPOSITORY DIGITAL & LEGAL DATA | ARCHIVE/BACKUP | MOSAIQ

Hospital Network (Data Center)

Radiotherapy Network and Facility

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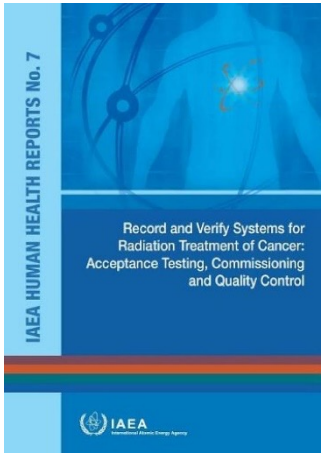
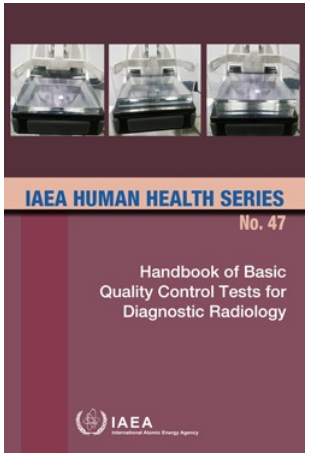
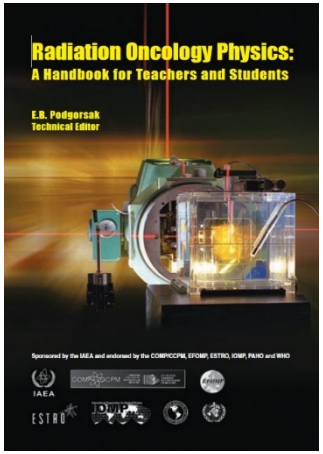
Imaging



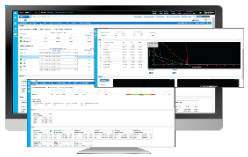




Is a WORLD
All in one day
Might is not possible

Treatment Planning Systems (Example)

Radiotherapy Network and Facility



AI – HPC Research

Monaco

Oncentra-Brachy

Raystation

MyQA & PerFraction

Planning and QA systems

- *Multimodality Imaging*
- *IVDT (Density table vs. HU)*
  - *MRI calculation capability*
  - *Density override*
- *Quantitative imaging*
  - *PET, SUV, etc..*
- *Contouring*
  - *Manual*
  - *Automatic*
  - *Model Based*
- *Co-Registration*
  - *Rigid (MI, CC)*
  - *Deformable registration*
  - *Dose Accumulation*
- *Physics Modeling*
- *Algorithm (CCC or Monte Carlo)*
- *Planning (photon, electron, etc..)*
- *Reconstruction (DRR, Synthetic, ecc..)*
- *DVH, Report and QA*
- *Connectivity (DICOM, DICOMRT, R&V)*
- *Artificial Intelligence*
  - *Machine Learning*
  - *Deep Learning)*
- *Auto Planning, Adaptive RT Modules*
- *Radiobiology*
- *Cybersecurity and AI*

Cybersecurity for AI

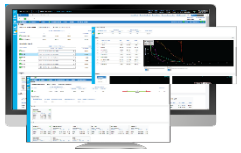
- Ransomware Impacting Healthcare
- Healthcare Industry Victimization by Ransomware
- Data Leak Trends
- Cyber Attack of Health System
- New Ransomware Capabilities
- Mitigations

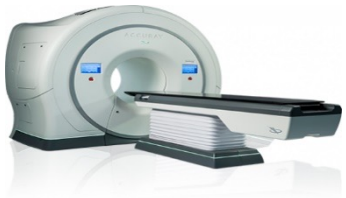
AI for Cybersecurity

- *Mitigations*
- *Machine Learning*
- *Network Scanning*
- *AI based Anomaly Detection*
- *…ask to your IT or Cybersecurity department…*
- *Know what we must do or avoid*
- *Know the problems and risks*

LINAC and On-Board Imaging (i.e. example)

Radiotherapy Network and Facility





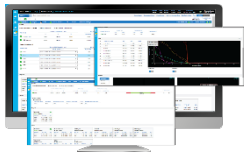
Hub Hospital
Treatment Machine

- *LINAC QA*
  - *Geometry and mechanical*
  - *Energy (FF/FFF) and Dosimetric*
  - *Inter/interleafs*
  - *MLC Interdigitation*
  - *Doserate*
  - *Gantry rotation speed*
  - *Safety and collision*
  - *Couch (Robotic and 6° freedom)*
  - *Complete procedure after interruption*
  - *TBI (Non-Standard conditions)*
- *VMAT, IMRT, dMLC, 3DCRT*
  - *MLC Interdigitation*
  - *Leafs speed*
  - *Penumbra*
- *CBCT/EPID/MVCT*
  - *Image Quality*
  - *Contrast/Uniformity*
  - *Bad Pixel Map*
  - *Image Density (IVDT)*
  - *Spatial resolutions*
  - *Geometric*
  - *Accuracy*
  - *Reconstructions*
  - *TBI imaging*
  - *Vivo Dosimetry*

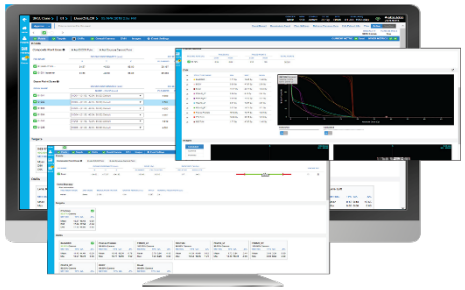
- *Radiosurgery, SBRT*
  - *Positioning (frame vs. frameless)*
  - *Accuracy*
  - *Rotational of gantry and collimator*
- *TBI (Total Body Irradiation)*
  - *Instruments and device*
  - *Vivo Dosimetry and device*
  - *Delivery (Non-Standard conditions)*
- *Non-Homogeneity condition*
  - *Cerrobend - Tray*
  - *Real-time monitor systems*
- *Non-medical device*
  - *Instruments*
  - *Barometers*
  - *IOS – R&V*
  - *Monitors*
  - *Safety (Camera and Door Interlock)*

Remote Site

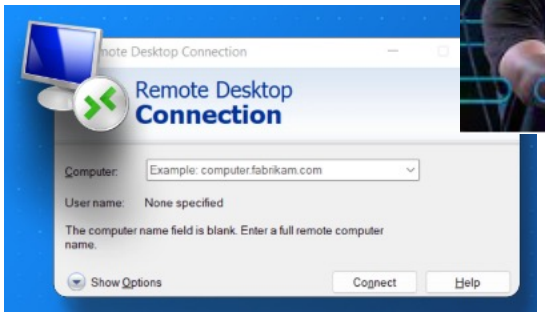
Radiotherapy Network and Facility



(Remote site)
Hospital
Treatment Machine



Issues to evaluate to have same performance

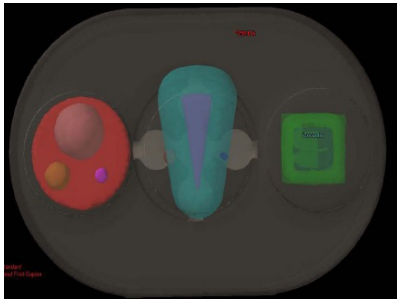


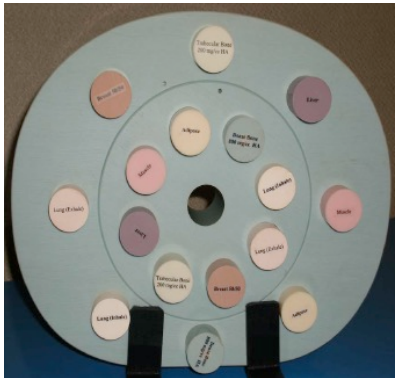
- ***Complete overview of the data from the Hub***
- ***Equal QA Program***
- ***Equal accuracy and frequency***

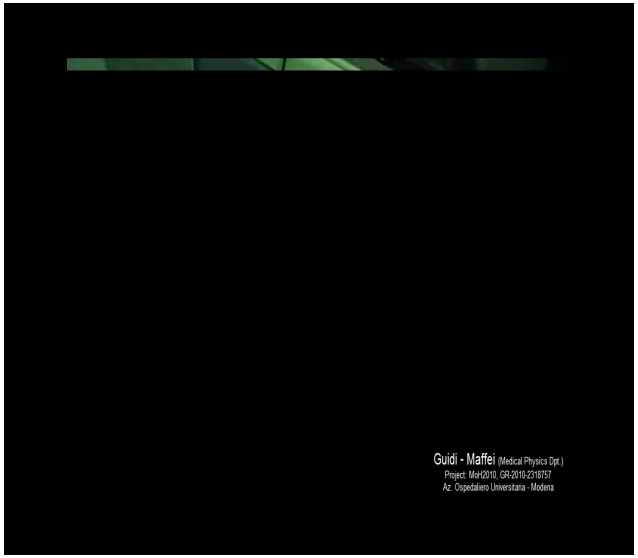
<u>Remote sites are not treating patients B!!</u>

QA – QUALITY ASSURANCE INSTRUMENTS
(i.e. Adaptive RT based on CBCT or phantom for gating verification)

	Region	*Homogenous, simple geometry*	*Complex geometry (wedge, inhomogeneity, asymmetry, blocks / MLC)*	*More complex geometries*****
δ_1	Central beam axis data - high high dose, low dose gradient	2%	3%	4%
δ_2*	Build-up region of central axis beam, penumbra ragion of the profiles - high dose, high dose gradient	2 mm or 10%	3 mm or 15%	3 mm or 15%
δ_3	Outside central beam axis region - high dose, low dose gradient	3%	3%	4%
δ_4**	Outside beam edges – low dose, low dose gradient	30% (3%)	40% (4%)	50% (5%)
RW_{50} ***	Radiological width – high dose, high dose gradient.	2 mm or 1%	2 mm or 1%	2 mm or 1%
δ_{50-90}	Beam fringe – high dose, high dose gradient	2 mm	3 mm	3 mm

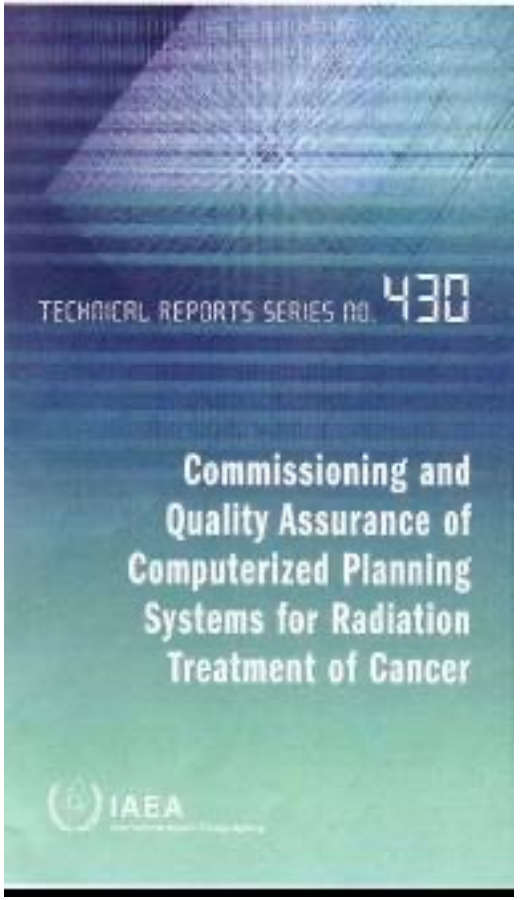


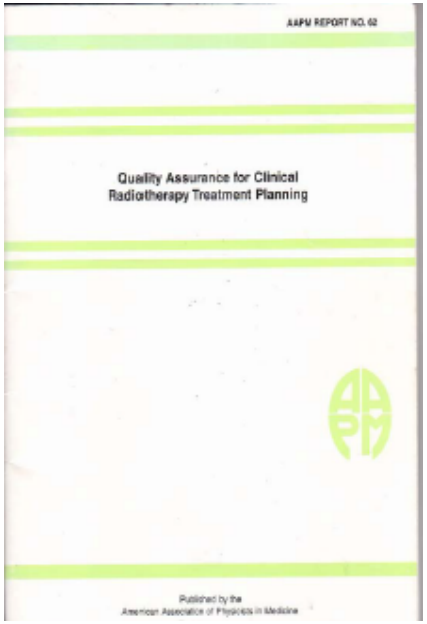


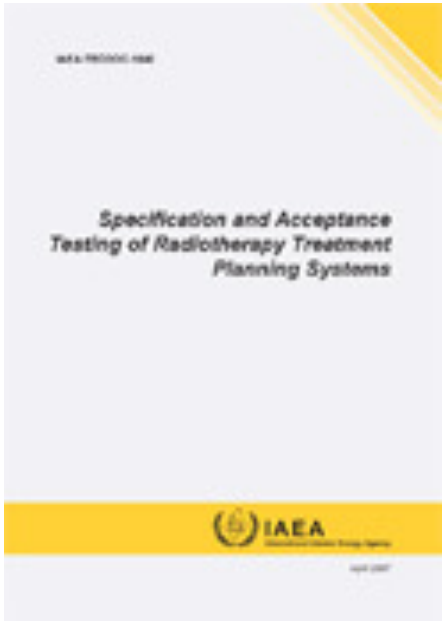


Treatment Planning Systems (Example Guideline)

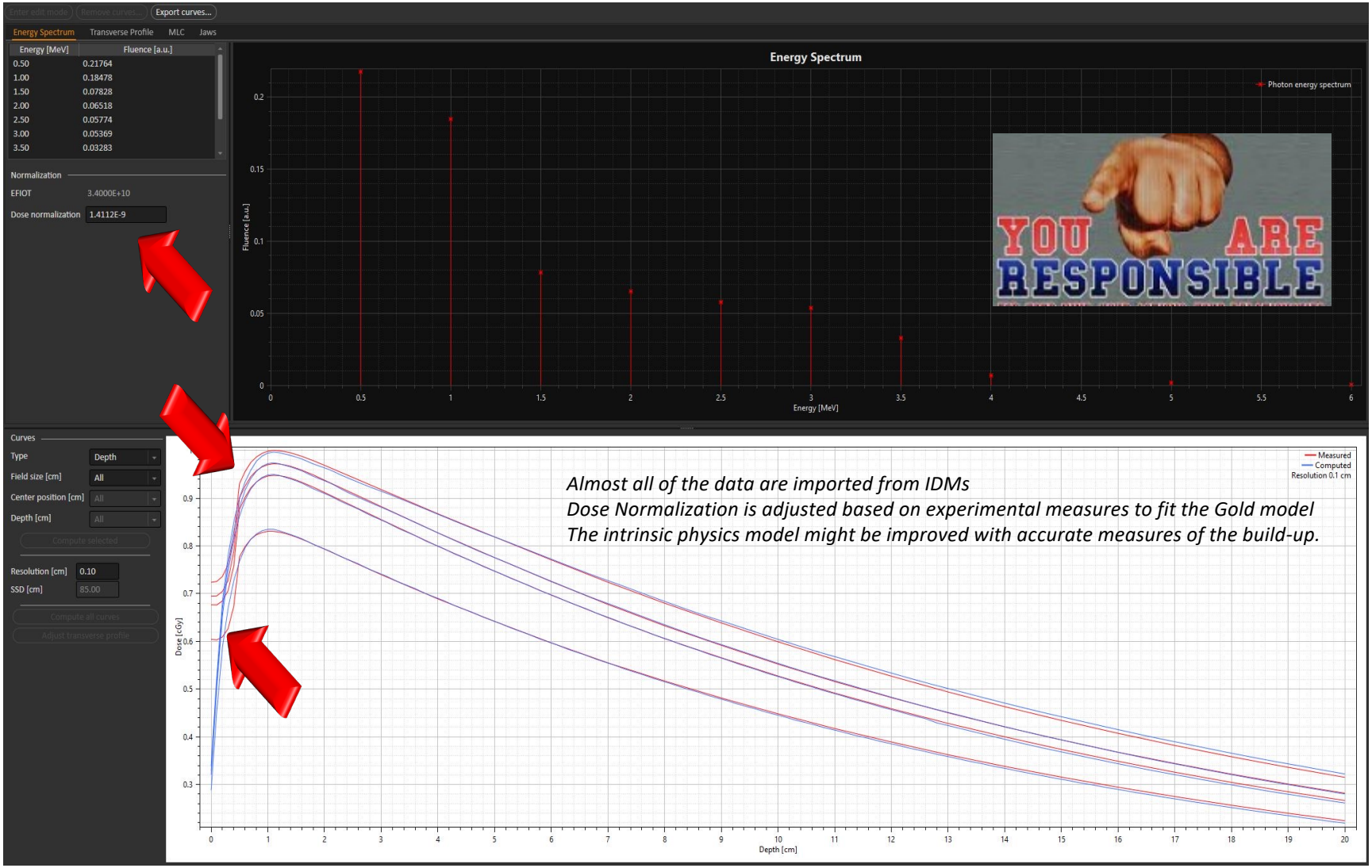
- *AAPM Report No. 62: Quality Assurance for Clinical Radiotherapy Treatment Planning (December 1998)*
- *Report of the AAPM Task Group No. 105: Issues associated with clinical implementation of Monte Carlo-based photon and electron external beam treatment planning (2007)*
- *IAEA Technical Report Series No. 430 : Commissioning and Quality Assurance of Computerized Planning Systems for Radiation Treatment of Cancer (October 2004)*
- *IAEA TEC-DOC No 1540: Specification for Acceptance Testing of Radiotherapy Treatment Planning Systems*
- *IAEA TEC-DOC No.1583: Report of the Coordinated Research Project on Development of Procedures for Quality Assurance of Dosimetry Calculations in Radiotherapy*



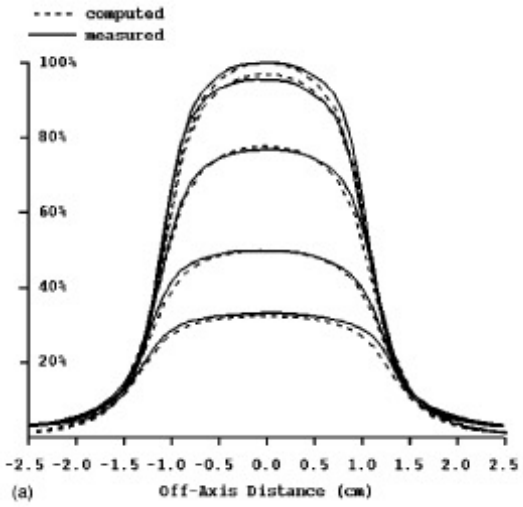


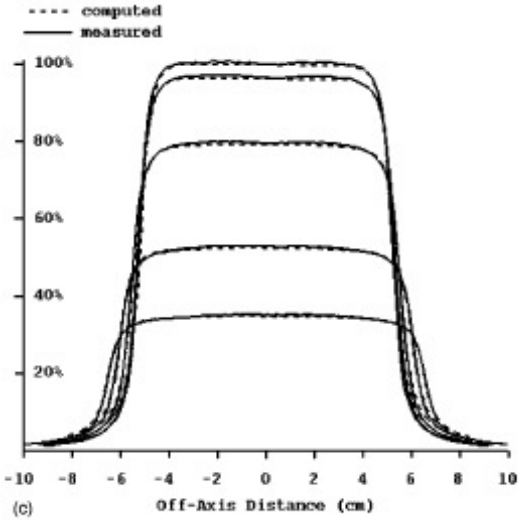


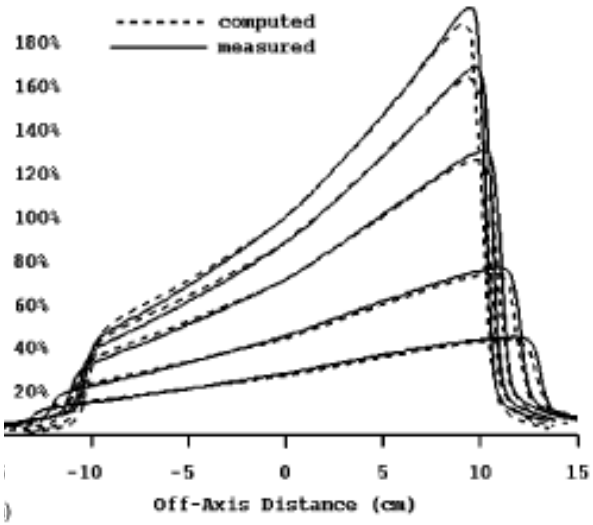
Physics Modeling
(Beware of the Gold Models or pre-commissioned factory data)

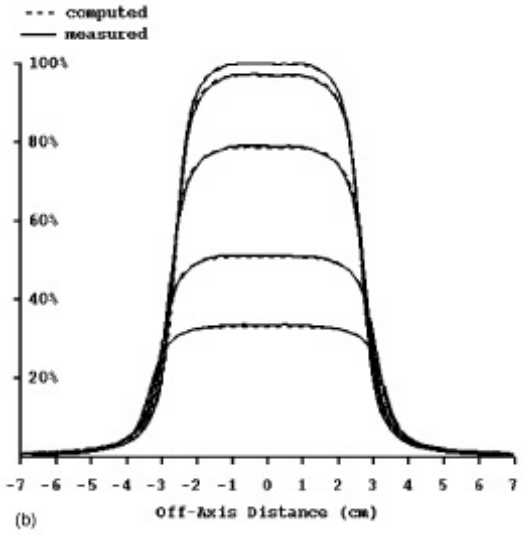


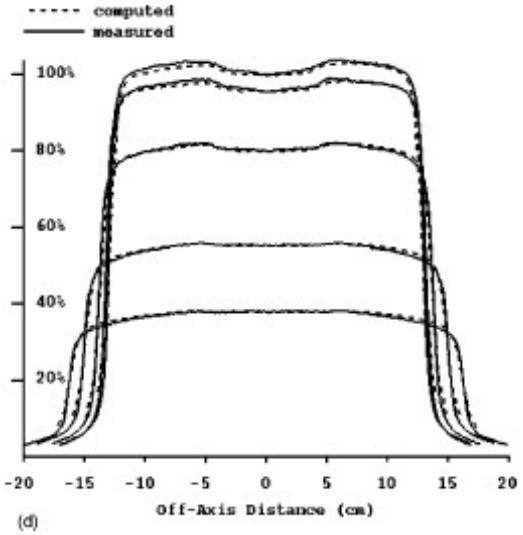
Modeling of the measures (Theory vs. Practice)

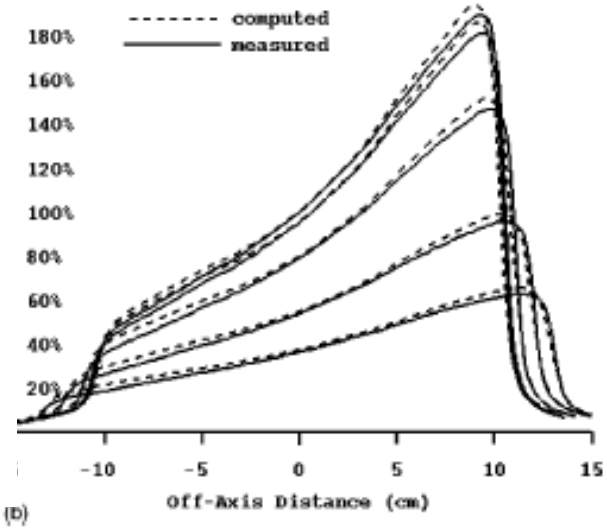




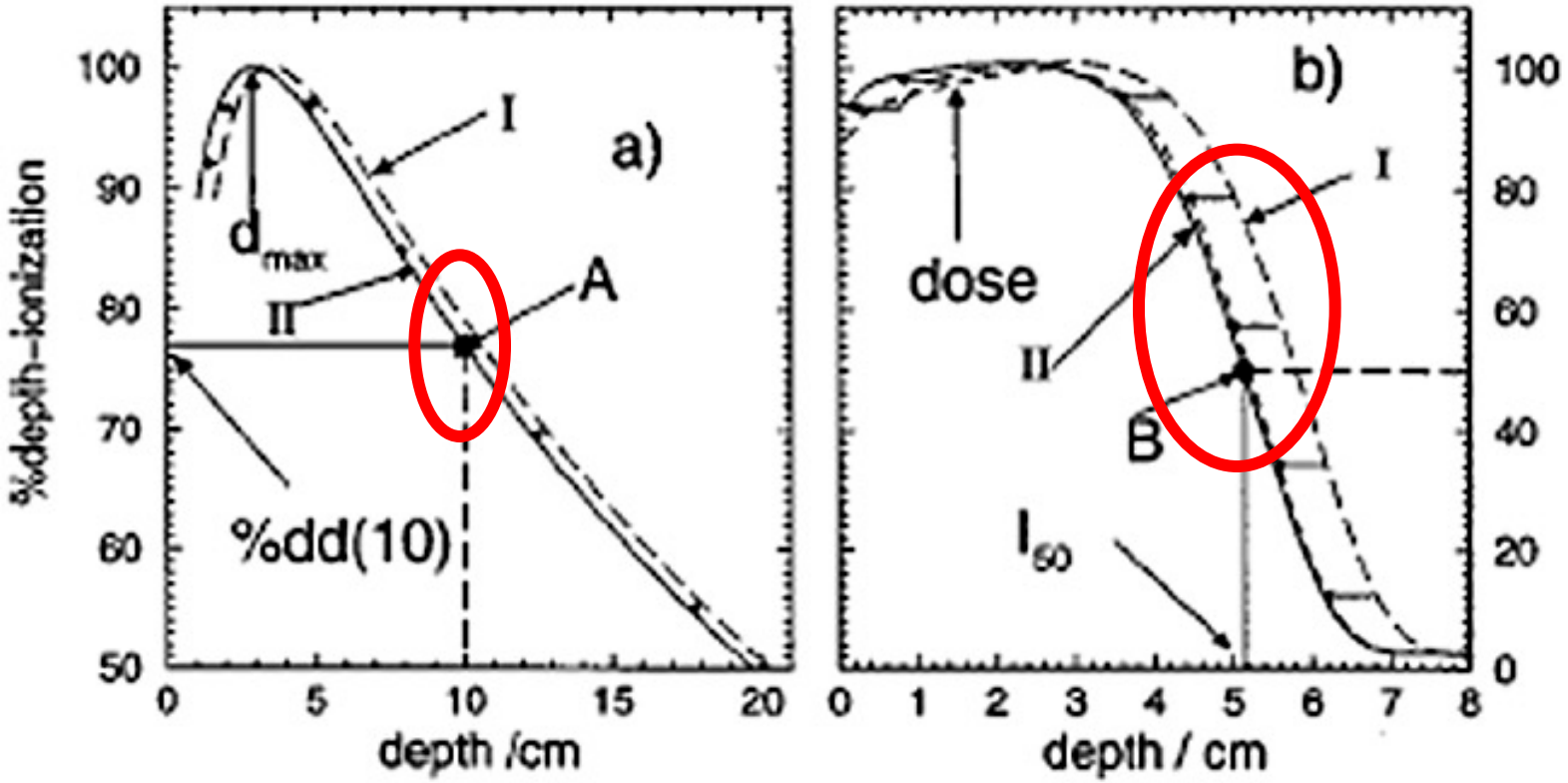








Effect of shifting depth-ionization data measured with cylindrical chambers upstream by 0.6 r_{cav} for photon beams and 0.5 r_{cav} for electron beams (with r_{cav} = 1.0 cm). For the electron beams, (b), further corrections are applied to obtain the %dd(x) curve shown.



SCATTER KERNEL

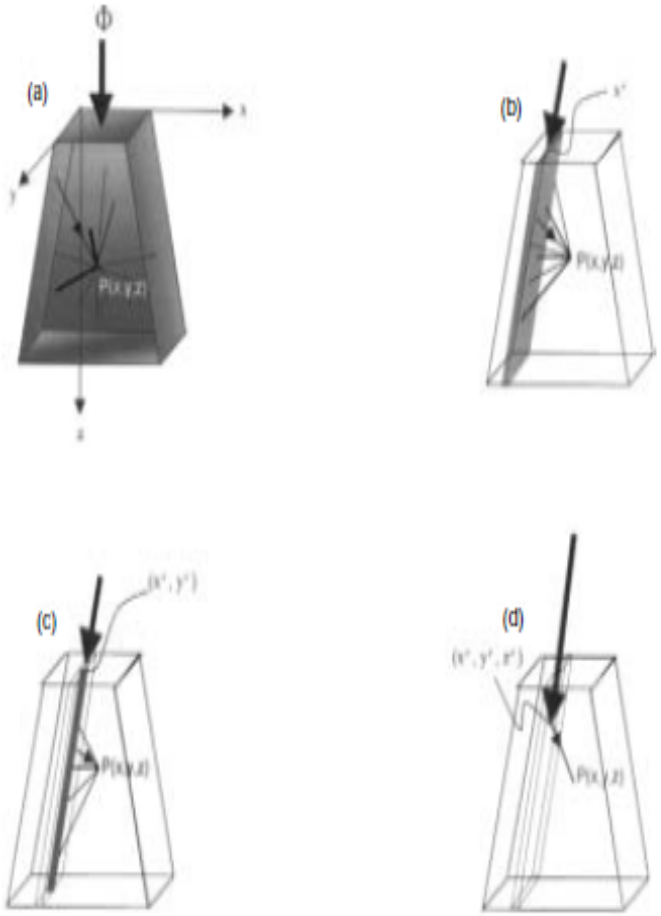
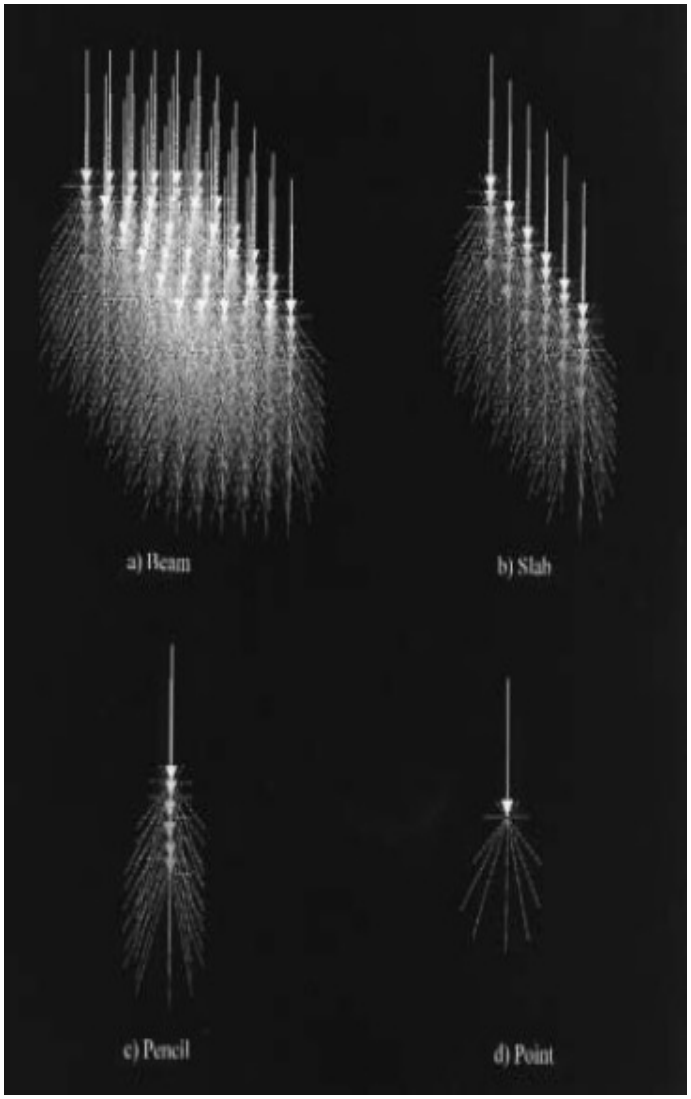
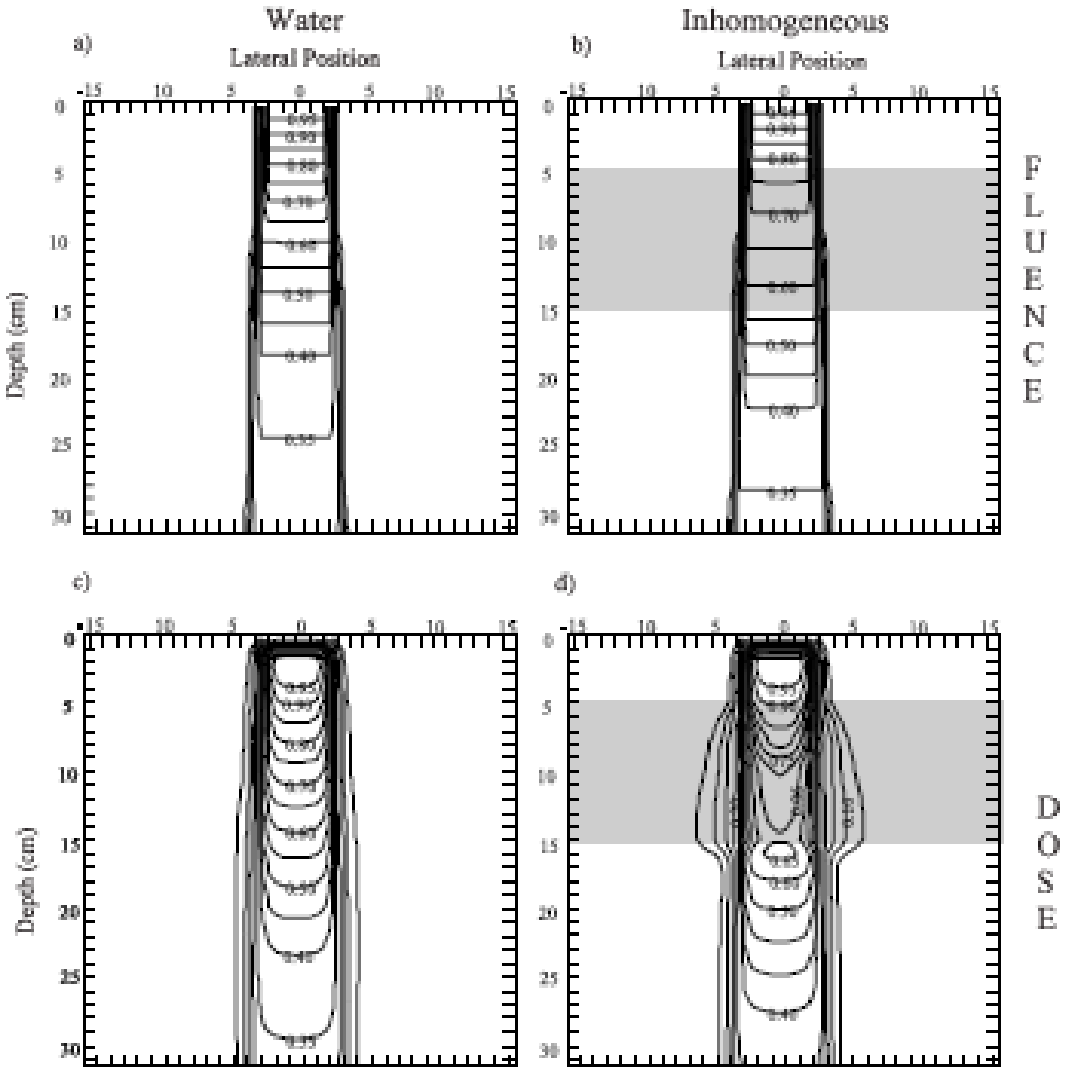


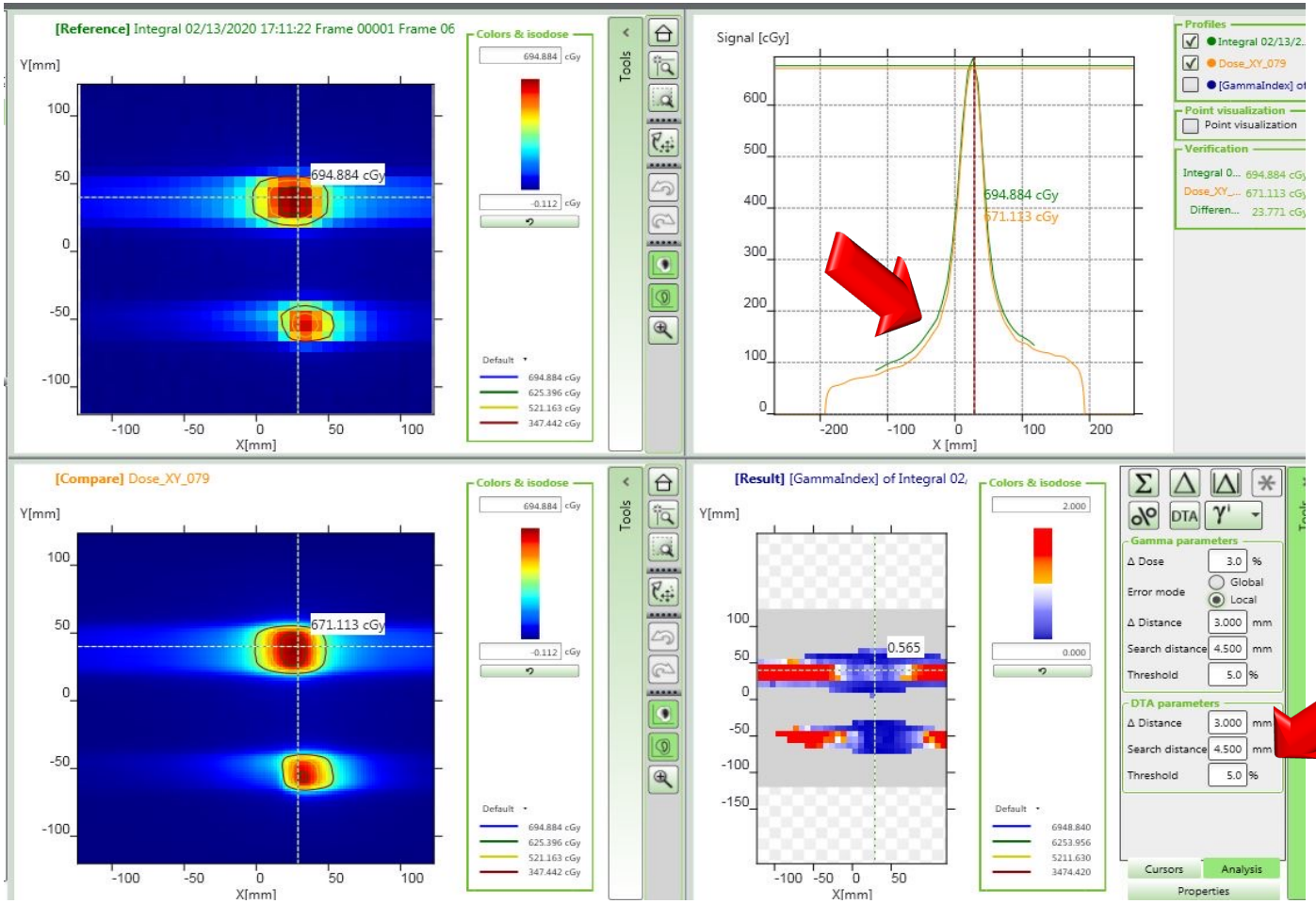
Figure 8.2
The summation of dose contribution from various scatter kernels, K. (a) Beam kernel, (b) Slab kernel, (c) Pencil beam kernel, (d) Point kernel. [Adapted with permission from reference [12].]



Fluence vs. Dose (Water vs. Inhomogeneous)



Dose profiles (High/Low dose range)

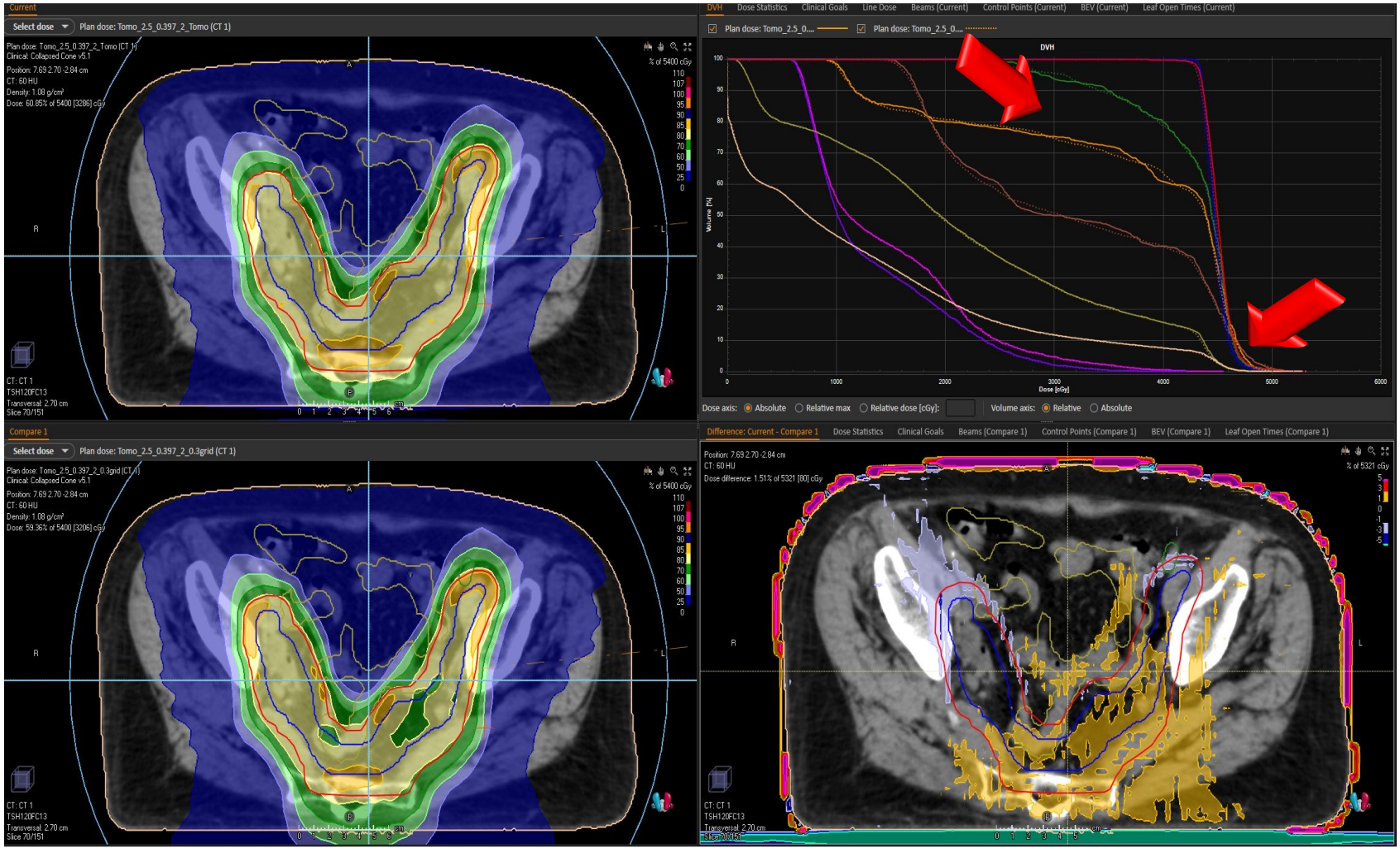


Using a threshold of dose related to the Maximum dose = 5%

- *Though of little relevance, the low dose area still might be modeled more accurately in the physics model*
- *The gradient appears to be calculated and delivered correctly even for high doses and small volumes (SRS/SBRT conditions)*
- *A Threshold of 5% is certainly very conservative, in the relevant dose ranges, dosimetry results are excellent when previously discussed planning strategies are followed*

Only minor dose distribution differences for different dose grids

Planning (0.5 cm dose grid) vs. *Final Plan Recalculated (*0.3 cm dose grid)



Might you do not appreciate by the DVH where is localized the dose difference?
Faster does not mean necessarily accurate.

LINAC QA and Guideline (i.e. AAPM, IEC, IAEA)

Task Group 142 report: Quality assurance of medical accelerators[a)]

Received: 9 February 2021 | Revised: 16 March 2021 | Accepted: 28 April 2021
DOI: 10.1002/mp.14992

AAPM SCIENTIFIC REPORT

MEDICAL PHYSICS

AAPM Task Group 198 Report: An implementation guide for TG 142 quality assurance of medical accelerators

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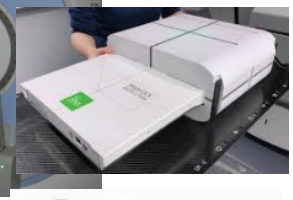
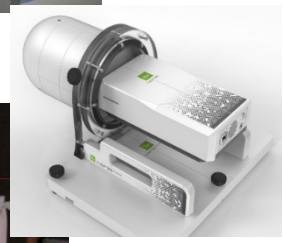
AAPM SCIENTIFIC REPORT

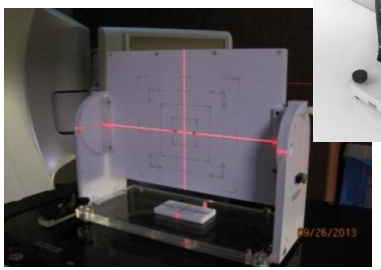
MEDICAL PHYSICS

AAPM Task Group Report 306: Quality control and assurance for tomotherapy: An update to Task Group Report 148

Quan Chen[1] | Yi Rong[2] | Jay W. Burmeister[3,4] | Edward H. Chao[5] | Nathan A. Corradini[6] | David S. Followill[7] | X. Allen Li[8] | An Liu[9] | X. Sharon Qi[10] | Hairong Shi[11] | Jennifer B. Smilowitz[12]







Are they still applicable to modern technologies? Any updated guidelines?

i.e. LINAC QA

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Define QA, frequency, tolerance, timing and personnel …

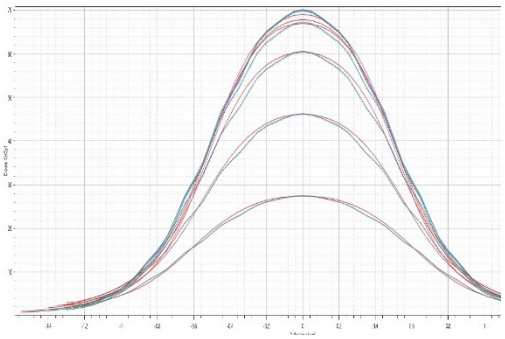
TABLE IV Time, staffing, and equipment requirements for annual QA.

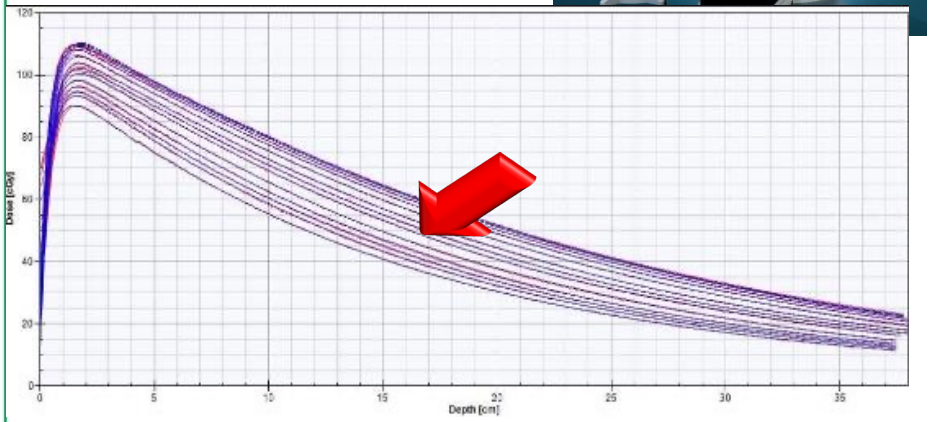
Procedure	Tolerance *Non-IMRT/IMRT/SRS*	Typical measuring device	Time required (range)	Personnel
Dosimetry				
Photon Flatness Change from Baseline	±1%	Large water tank	60–120 min	QMP
Photon Symmetry Change from Baseline	±1%	Large water tank	60–120 min	QMP
Electron Flatness Change from Baseline	±1%	Large water tank	60–120 min	QMP
Electron Symmetry Change from Baseline	±1%	Large water tank	60–120 min	QMP
Photon/Electron Output Calibration[38]	± 1% (Absolute)	Small/large water tank. ADCL Calibrated Ionization Chamber/ Electrometer	120–180 min	QMP
Spot Check of Field Size-Dependent Output Factors for Photon (2 or more field sizes)	±2% for field sizes < 4 × 4 cm^2; ±1% for field sizes ≥ 4 × 4 cm^2	Ionization Chamber/ Electrometer, solid phantom or water phantom	30–60 min	QMP
Output Factors for Electron Applicators (spot check of one applicator/energy)	± 2% from baseline	Ionization Chamber/ Electrometer, solid phantom or water phantom	60–90 min	QMP
Photon Beam Quality (PDD_{10} or $TMR_{20:10}$)	± 1% from baseline	Large water tank	30–60 min	QMP
Electron Beam Quality (R_{50})	± 1 mm	Large water tank	60–90 min	QMP
Physical Wedge Transmission Factor constancy	± 2%	Ionization Chamber/ Electrometer, solid phantom or water phantom	30–60 min	QMP
Photon Monitor Unit Linearity (Output Constancy)	± 2% ≥ 5 MU ± 5% (2–4) MU, ± 2% ≥ 5 MU ± 5% (2–4) MU, ± 2% ≥ 5 MU	Ionization Chamber/ Electrometer, solid phantom or water phantom	30–60 min	QMP
Electron Monitor Unit Linearity (Output Constancy)	± 2% ≥ 5 MU	Ionization Chamber/ Electrometer, solid phantom or water phantom	30–60 min	QMP
Photon Output Constancy vs Dose Rate	± 2% from clinical dose rate	Ionization Chamber/ Electrometer, solid phantom or water phantom	30–60 min	QMP
Photon Output Constancy vs Gantry Angle	± 1% of the value acquired at gantry 0	Ionization Chamber/ Electrometer. 2D/3-D Diode array	30–90 min	QMP

TABLE VII Time/Staffing/Equipment requirements for Imaging QA.

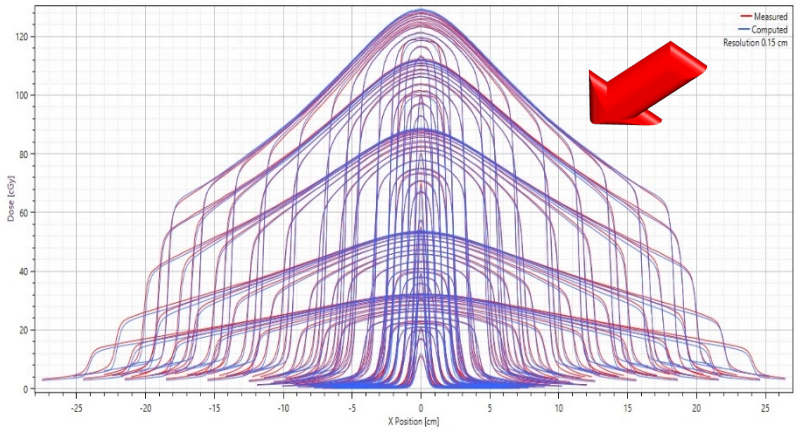
Procedure	Tolerance *Non-SRS/SBRT SRS/ SBRT*	Typical measuring device	Time required (range)	Personnel
Daily				
Planar kV and MV (EPID) imaging				
Collision interlocks	Functional	NA	5 min	RTT
Positioning/repositioning	≤2 mm / ≤2 mm/≤1 mm day of SRS	Phantom containing radiopaque markers.	10–15 min	RTT
Imaging and treatment coordinate coincidence	≤2 mm / ≤2 mm/≤1 mm day of SRS	Phantom containing radiopaque markers.	Included above.	RTT
Cone beam CT (kV and MV)				
Collision interlocks	Functional	NA	5 min	RTT
Positioning/repositioning	≤2 mm / ≤2 mm/≤1 mm day of SRS	Phantom containing radiopaque markers.	10–15 min	RTT
Imaging and treatment coordinate coincidence	≤2 mm / ≤2 mm/≤1 mm day of SRS	Phantom containing radiopaque markers.	Included above.	RTT
Monthly				
Planar MV imaging (EPID)				
Imaging and treatment coordinate coincidence	≤2 mm / ≤1 mm	Phantom containing radiopaque markers.	15–20 min	QMP or Designee
Scaling	≤2 mm / ≤1 mm	Object of known dimensions	5 min	QMP or Designee
Spatial resolution	≥ Baseline	Manufacturer supplied test phantom	5–10 min	QMP or Designee
Contrast	≥ Baseline	Manufacturer supplied test phantom	5–10 min	QMP or Designee
Uniformity and noise	≥ Baseline	Manufacturer supplied test phantom	5–10 min	QMP or Designee
Planar kV imaging				
Imaging and treatment coordinate coincidence	≤2 mm / ≤1 mm	Phantom containing radiopaque markers.	15–20 min	QMP or Designee
Scaling	≤2 mm / ≤1 mm	Object of known dimensions	5 min	QMP or Designee
Spatial resolution	≥ Baseline	Manufacturer supplied test phantom	5–10 min	QMP or Designee
Contrast	≥ Baseline	Manufacturer supplied test phantom	5–10 min	QMP or Designee
Uniformity and noise	≥ Baseline	Manufacturer supplied test phantom	5–10 min	QMP or Designee
Cone beam CT (kV and MV)				
Geometric distortion	≤2 mm / ≤1 mm	phantom of known and dimensions	15–20 min	QMP or Designee
Spatial resolution	≥ Baseline	Object of known dimensions	5 min	QMP or Designee
Contrast	≥ Baseline	Manufacturer supplied test phantom	5–10 min	QMP or Designee
HU constancy	± 40 HU from baseline	Manufacturer supplied test phantom	5–10 min	QMP or Designee

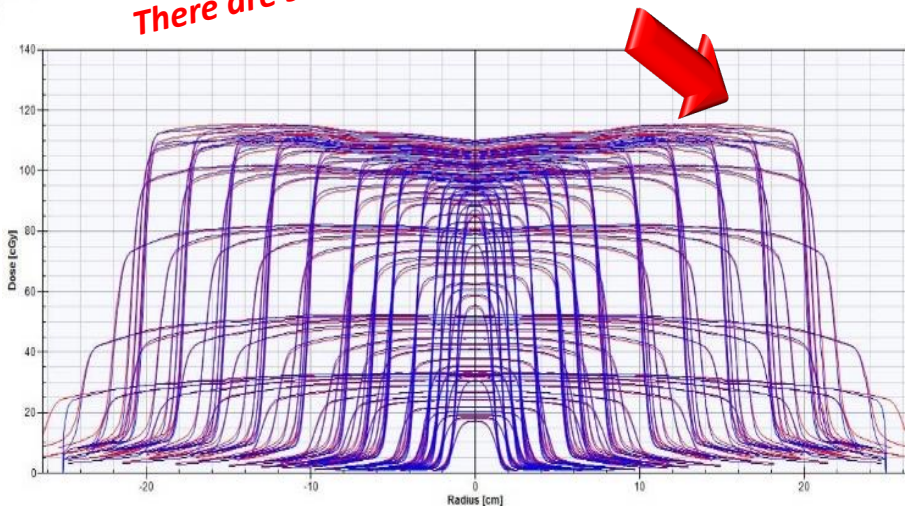
Beam Matching – No.4 LINAC (6,10,15 MV FF and FFF)





All in one
Might a compromise be necessary
Vendors commonly impose their own standards, but these standards may not be compatible with clinical needs (e.g. SBRT, RS).
There are still no clear indications and guidelines

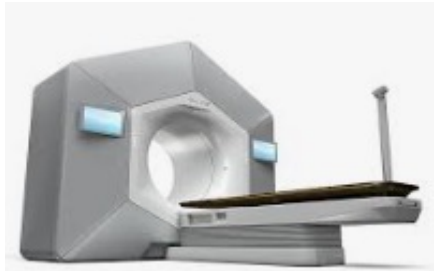
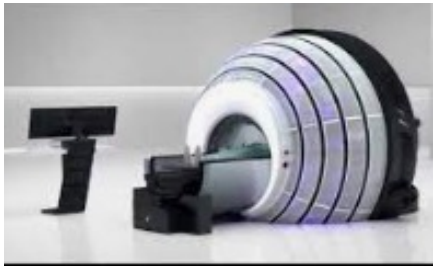




IMAGING QA

Procedure	Application-type tolerance: non-SRS/SBR	Application-type tolerance: SRS/SBRT
Daily[a]		
Planar kV and MV (EPID) imaging		
Collision interlocks	Functional	Functional
Positioning/repositioning	≤2 mm	≤1 mm
Imaging and treatment coordinate coincidence (single gantry angle)	≤2 mm	≤1 mm
Cone-beam CT (kV and MV)		
Collision interlocks	Functional	Functional
Imaging and treatment coordinate coincidence	≤2 mm	≤1 mm
Positioning/repositioning	≤1 mm	≤1 mm
Monthly		
Planar MV imaging (EPID)		
Imaging and treatment coordinate coincidence (four cardinal angles)	≤2 mm	≤1 mm
Scaling[b]	≤2 mm	≤2 mm
Spatial resolution	Baseline[c]	Baseline
Contrast	Baseline	Baseline
Uniformity and noise	Baseline	Baseline
Planar kV imaging[d]		
Imaging and treatment coordinate coincidence (four cardinal angles)	≤2 mm	≤1 mm
Scaling	≤2 mm	≤1 mm
Spatial resolution	Baseline	Baseline
Contrast	Baseline	Baseline
Uniformity and noise	Baseline	Baseline
Cone-beam CT (kV and MV)		
Geometric distortion	≤2 mm	≤1 mm
Spatial resolution	Baseline	Baseline
Contrast	Baseline	Baseline
HU constancy	Baseline	Baseline
Uniformity and noise	Baseline	Baseline
Annual (A)		
Planar MV imaging (EPID)		
Full range of travel SDD	±5 mm	±5 mm
Imaging dose[e]	Baseline	Baseline
Planar kV imaging		
Beam quality/energy	Baseline	Baseline
Imaging dose	Baseline	Baseline
Cone-beam CT (kV and MV)		
Imaging dose	Baseline	Baseline

We are doing daily imaging of the patients for setup and Adaptive RT purposes.
Which is the best QA frequency and tolerance?
What are you planning with the next generation of Hybrid-Machine?

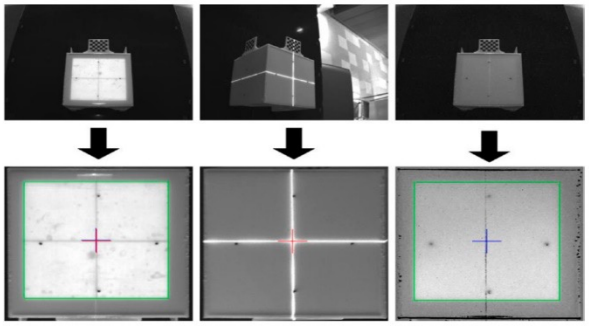



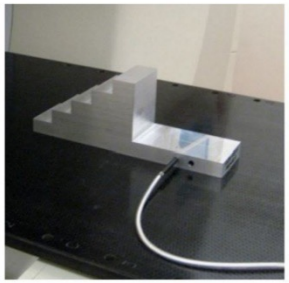
SOMETIME OBJECTS AND PHANTOM CAN HELP THE WORK-LIFE

IOP Publishing Institute of Physics and Engineering in Medicine Physics in Medicine & Biology
Phys. Med. Biol. 61 (2016) L29–L37 doi:10.1088/0031-9155/61/17/L29

Fast Track Communication

Automating quality assurance of digital linear accelerators using a radioluminescent phosphor coated phantom and optical imaging





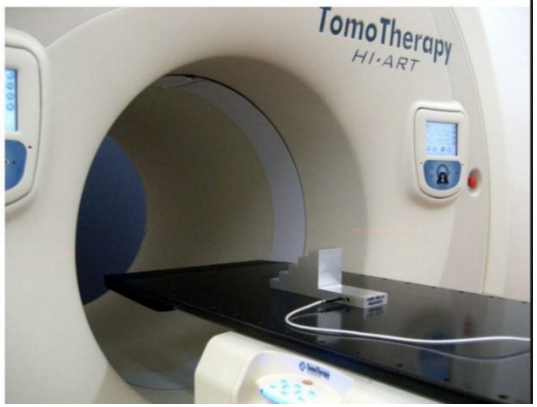
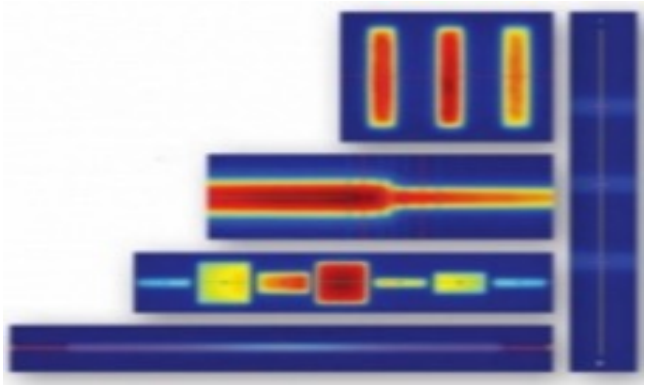


Table 2. System results compared to existing methods.

Light field/ radiation alignment	Symmetric beams	Center shift *X* (mm)	Center shift *Y* (mm)	Width difference (mm)	Height difference (mm)
Auto	5 × 5 cm	−0.02 ± 0.05	0.68 ± 0.11	−0.58 ± 0.05	−0.59 ± 0.09
Auto	10 × 10 cm	−0.21 ± 0.07	0.96 ± 0.12	−0.63 ± 0.15	−0.94 ± 0.31
FC-2	*15 × 15 cm*	*−0.19*	*0.40*	*−0.30*	*0.00*
	Asymmetric beams		Difference in position (mm)		
	(*X1*, *X2*, *Y1*, *Y2*)	*X1*	*X2*	*Y1*	*Y2*
Auto	(−3, 4, −3, 4) (cm)	0.23 ± 0.03	−0.39 ± 0.05	−0.26 ± 0.06	−0.95 ± 0.07
Jaw position indicators	Symmetric beams	Width Difference (mm)	Height Difference (mm)		
Auto	5 × 5 cm	−0.76 ± 0.02	−1.73 ± 0.06		
Auto	10 × 10 cm	−0.46 ± 0.16	−1.71 ± 0.19		
Iso-align	*5 × 5 cm*	*0.0*	*−2.0*		
Iso-align	*10 × 10 cm*	*0.0*	*−2.0*		
	Asymmetric beams		Difference in position (mm)		
	(*X1*, *X2*, *Y1*, *Y2*)	*X1*	*X2*	*Y1*	*Y2*
Auto	(−3, 4, −3, 4) (cm)	0.06 ± 0.06	0.80 ± 0.03	1.40 ± 0.16	0.63 ± 0.21
Iso-align	*(−5, 2.5, −5, −2.5)* (cm)	*0.0*	*1.0*	*1.0*	*1.0*
Cross-hair centering	Center shift *X* (mm)	Center shift *Y* (mm)	Walkout (mm)		
Auto	−0.35 ± 0.03	0.77 ± 0.01	0.87 ± 0.12		
FC-2/Iso-align	*−0.25*	*0.67*	*0.5*		
Couch position	Shifts (lat., long.) (mm)	Lat. (mm)	Long. (mm)		
Auto	(30, 30)	30.17 ± 0.25	30.22 ± 0.15		
Ruler	*(200, 300)*	*200.3*	*300.4*		
Laser localization (relative to cross hairs)	Center shift *X* (mm)	Center shift *Y* (mm)			
Auto	0.19 ± .30	−0.26 ± 0.13			
Iso-align	*0.25*	*−0.25*			

Note: Summary of tests performed by the autonomous system (mean ± standard deviation) and comparison to current QA techniques (shown in italics).

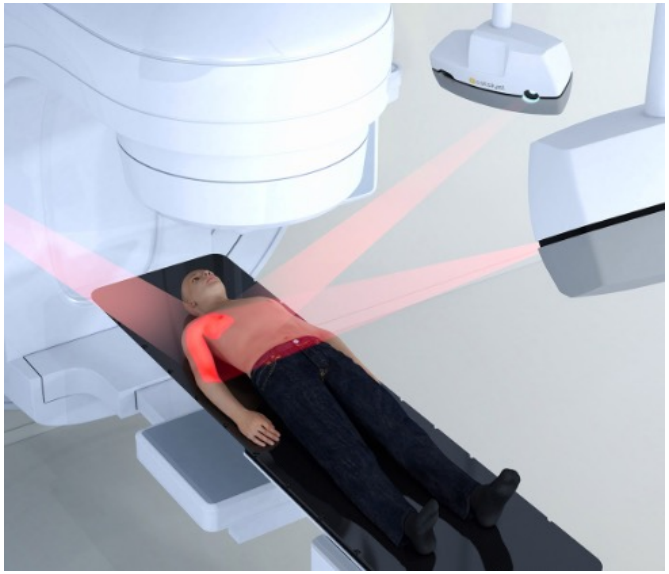


IMAGING QA (forgot something?)

Dicom or Non-Dicom monitor for Adaptive RT? Frequently are provided TV Conversions, instead medical device monitor …. Might the non-medical devices could hide some unexpected issues

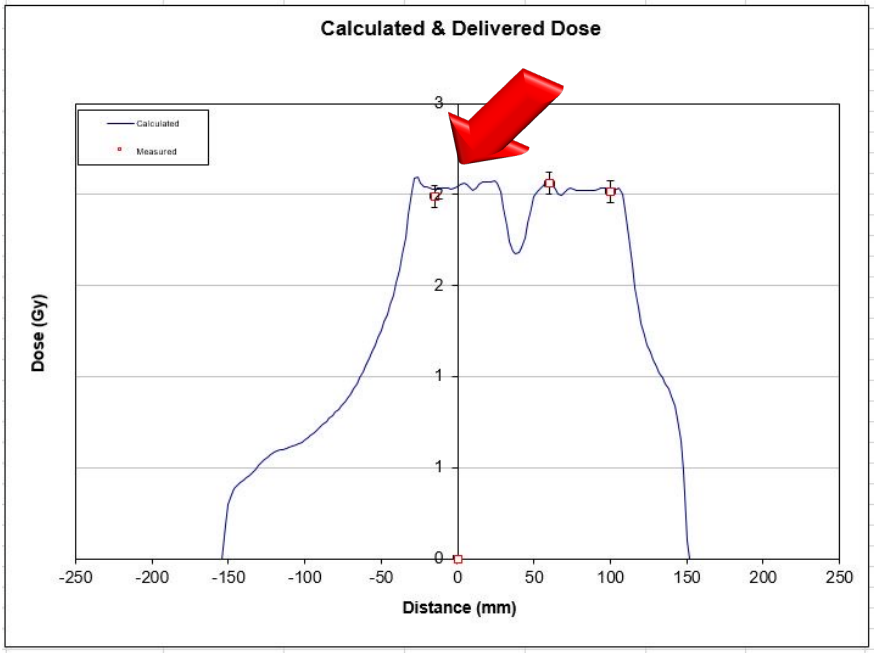
US (Ultrasound device)
Spatial alignment, repositioning and image quality

Surface tracking, robotic couch and LINAC and Imaging device isocenter should be aligned.



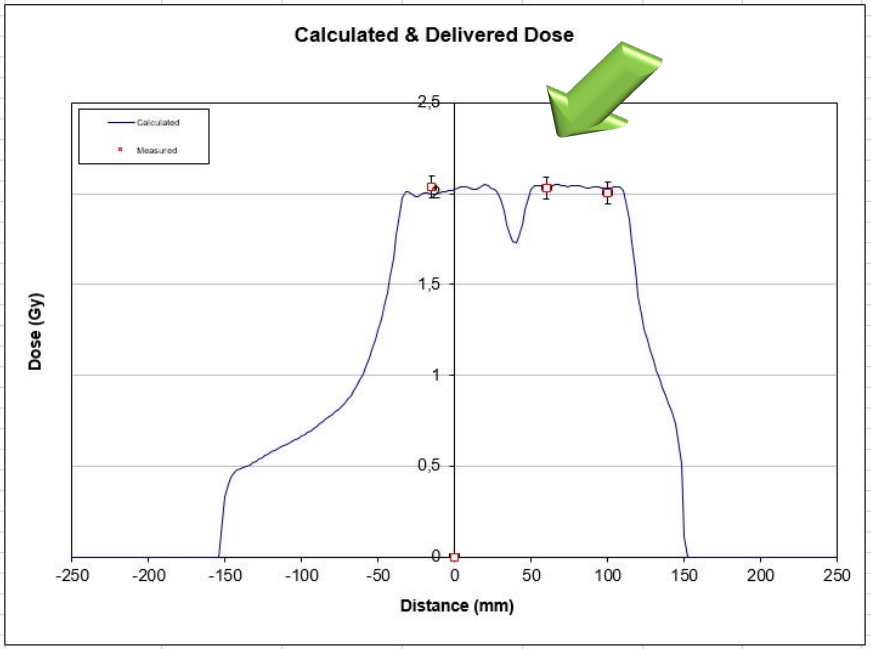
Calibration of the Output after the Upgrade

Measured	IEC X	Calculated Plan	Calculated fraction	Var. %
Dose (Gy)	Position (mm)	Dose in ROI 0,05 cm^3	Dose in ROI 0,05 cm^3	
1,9901	-15,0	9859	1,972	0,92
2,0609	60,0	10414	2,083	-1,06
2,0162	100,0	10140	2,028	-0,59



Relative variations were compliant with the machine specification requirements, but asymmetrical along the profile. Absolute dose was therefore more asymmetrical than expected (2Gy)

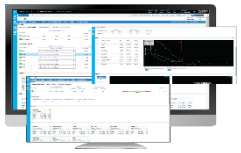
Measured	IEC X	Calculated Plan	Calculated fraction	Var. %
Dose (Gy)	Position (mm)	Dose in ROI 0,05 cm^3	Dose in ROI 0,05 cm^3	
2,0353	-15,0	10076	2,0152	0,99
2,0323	60,0	10288	2,0576	-1,25
2,0047	100,0	10097	2,0194	-0,73



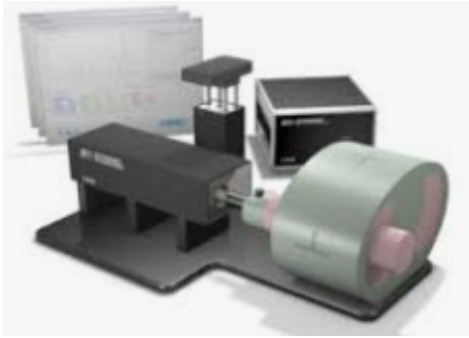
Accurate recalibration, always within Service Engineering requirements, improves dosimetrical results

Software, 3rd Part device, Brachytherapy, Other systems (i.e. example)

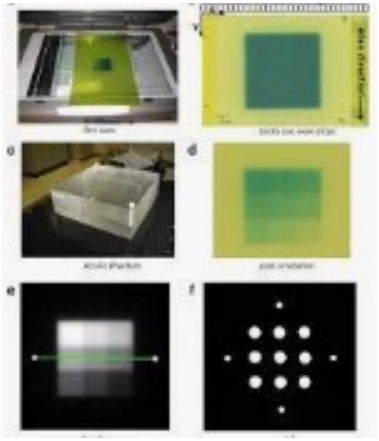
Radiotherapy Network and Facility



- *4D Radiation-Therapy*
  - *Breath synch*
  - *Beam on/off and delivery (DIBH)*
  - *Ramp-up of the beam-on*
  - *Surface tracking systems*
- *Complete procedure after interruption*
  - *3DCRT*
  - *IMRT, dMLC or Sliding Windows*
  - *VMAT*
  - *Radiosurgery, SBRT*
- *Isocenter junction*
  - *Junction of the beam and divergence*
- *Log files connectivity and Software analysis*
- *Unpredictable cases (near missing or errors)*
- *Connectivity with IOS*
- *…….radiation therapy*

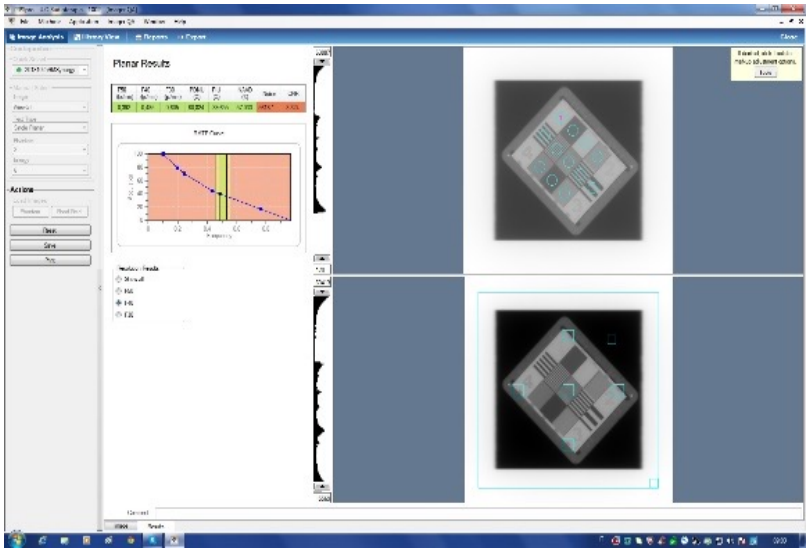


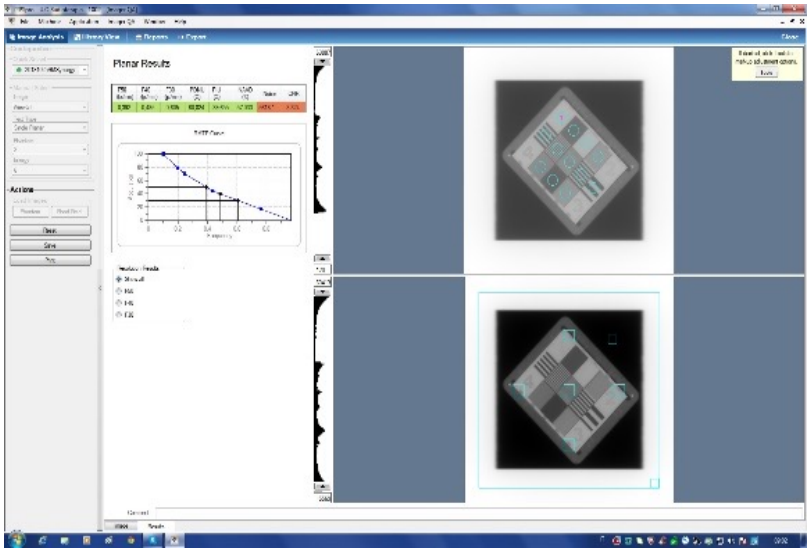
Hub Hospital
Treatment Machine

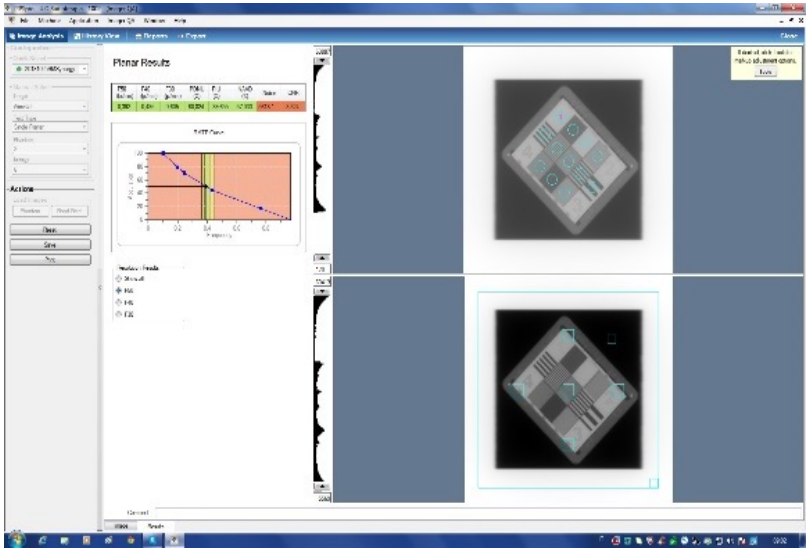


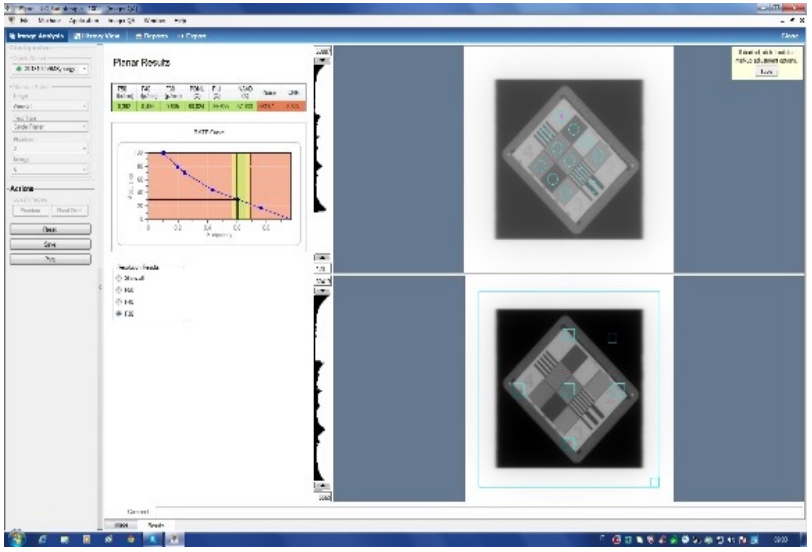
- *Brachytherapy*
  - *Delivery Systems*
  - *Positioning and accuracy*
  - *Source calibration*
  - *Applicator reconstruction*
  - *Instruments*
  - *CT/MR compatibility*
  - *CT/MR Calculations*
  - *Registration, Contouring*
  - *Dose Accumulation*
  - *Safety and Interlocks*
  - *Monitor*
  - *Vivo Dosimetry*

DEFINE THE BASELINE AND REPEAT FREQUENTLY (AS LOW AS REASONABLE) THE QA TEST

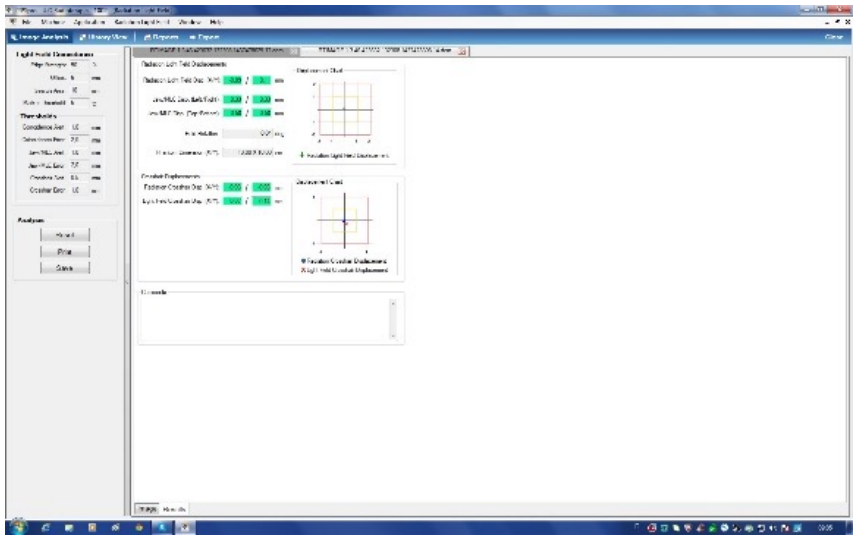


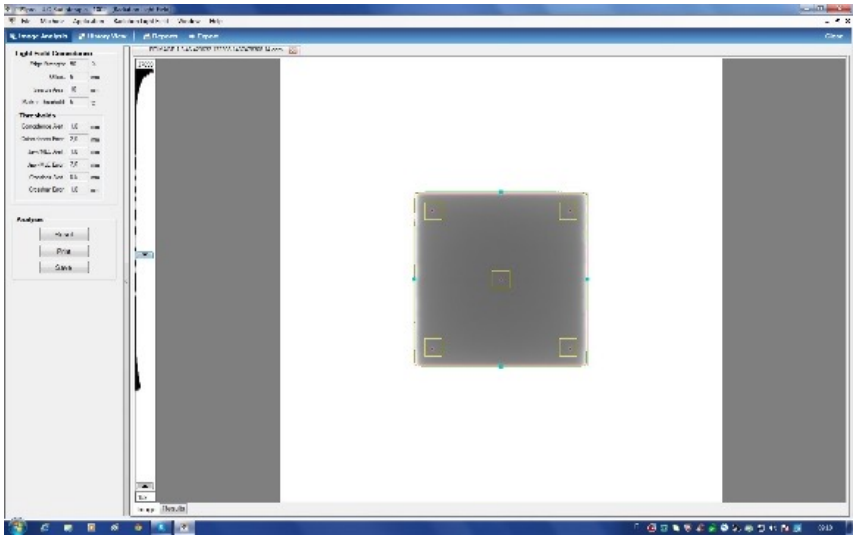


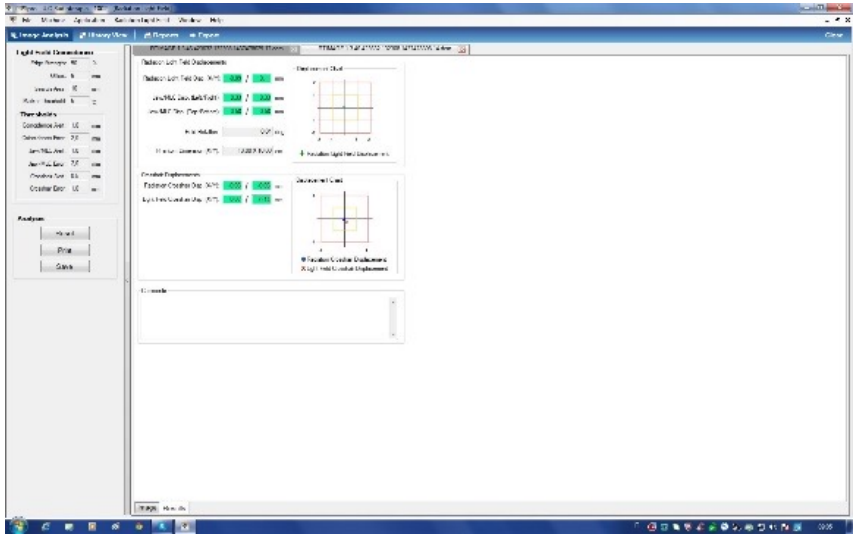




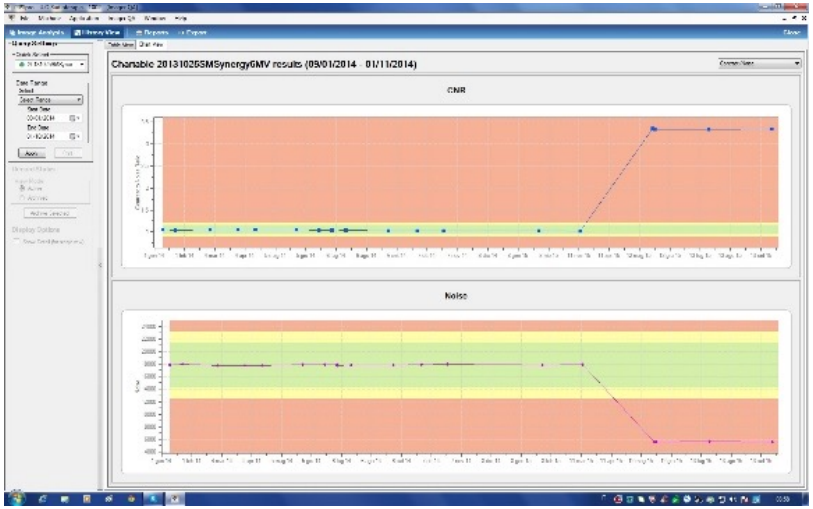
i.e. Isocenter and MLC position (Picket, Fence) Tests

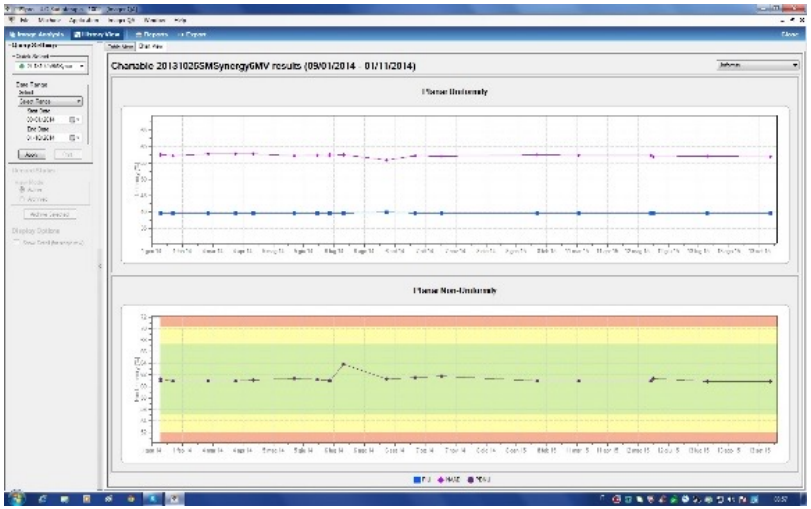


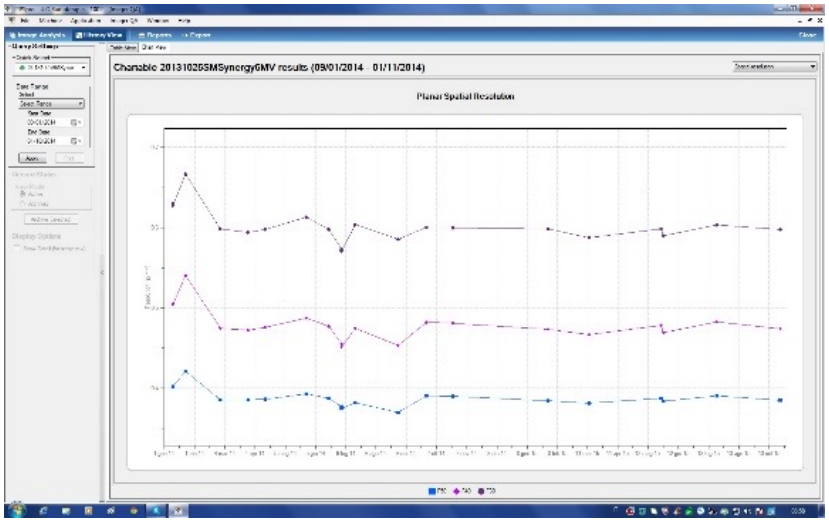




QA on practice – Setting a baseline and comparing trends



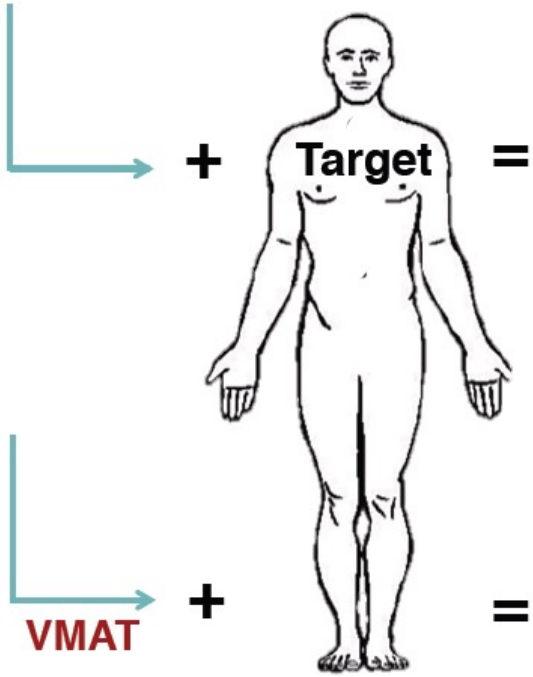




Total Body Irradiation – Introduction

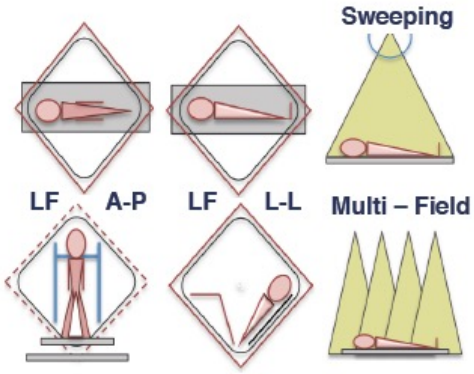
Clinical RT Techniques

- **3D-CRT:** Direct radiation beams to conform the shape of the target.
- **IMRT:** Manipulation of beam to conform the target by varying intensities.
- **IGRT:** Incorporation of imaging techniques during treatment session.
- **VMAT: Delivery of Radiation from a continuous rotation of the source.**



Total Body Irradiation is a MV technique that provides a uniform irradiation of the entire body.

- *Radiotherapy Unit*
- *Bunker Size*
- *Field Size*
- *Patient Supports*
- *Transmission Shield*



= Total Body Irradiation with Modulated Arc Beam

Gutierrez, Maria Victoria

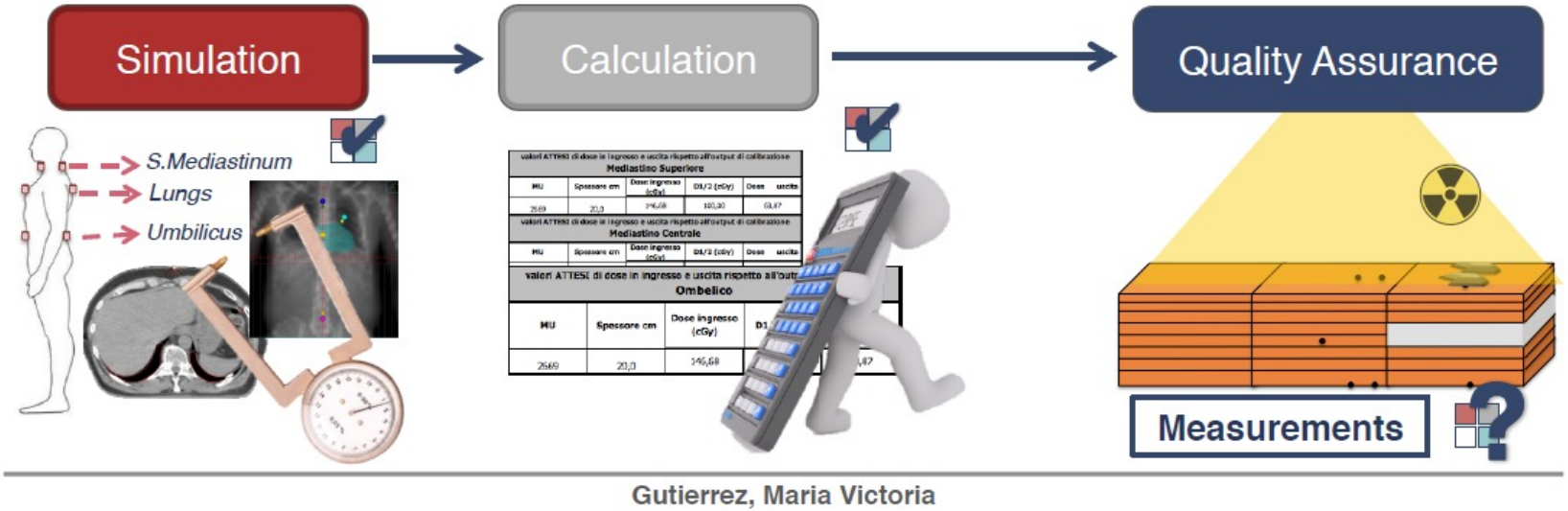
TBI QA Programme

Quality Assurance Programme

SCOPE of QA Program

→ To prevent:
- Stress and Anxiety;
- Mistakes;
- Malfunction or defects on the dosimetry system;
- Malfunction on RT machine.

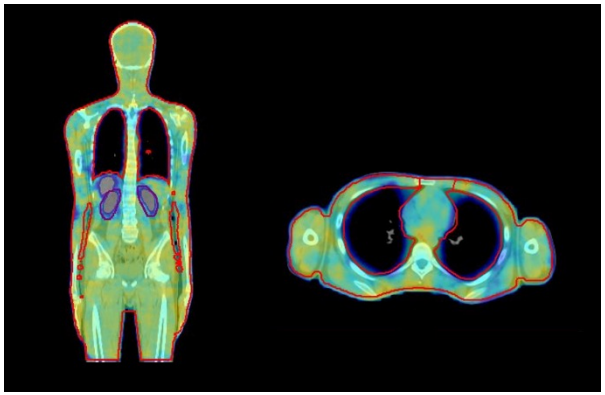
→ To evaluate:
- Internal processes and procedures are functioning;
- Human resources handle with the assigned tasks.

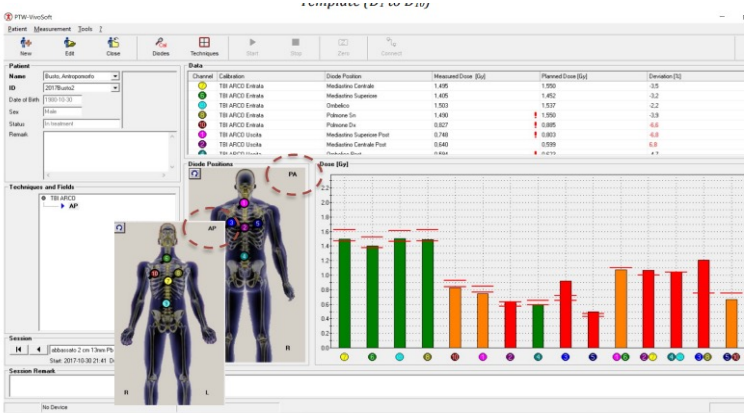


Gutierrez, Maria Victoria

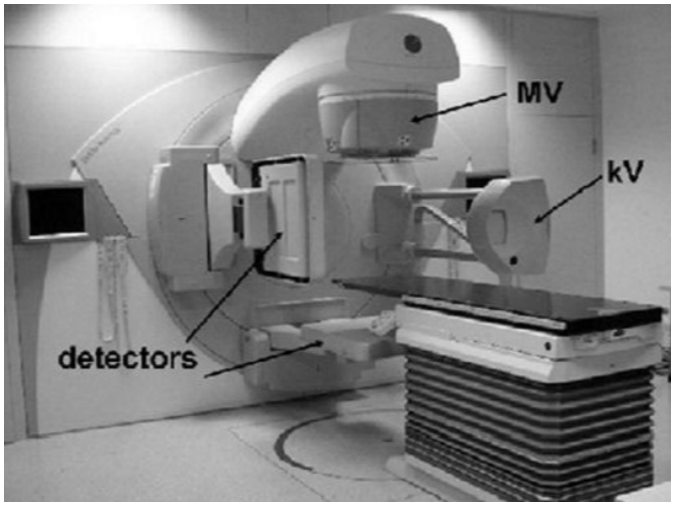
TBI QA Programme (Vivo Dosimetry)

Object	Parameter to control	Modality of the control
LINAC or telecobalt	Dose	Control of constancy
Personalize beam modifiers (protection, shields, compensators, bolus)	Attenuation of the shields Consistency of compensators and bolus	Dosimetric measures
Positioning devices	Geometric parameters (distance from the source, height from the pavement etc.)	Metric control
In vivo dosimetry	Sensitivity	Calibration in terms of absorbed dose or control relative to the response
Basic dosimetriy	Dose in standard phantom at reference depth	Audit or external confrontation in TBIconditions; calibration according to international protocols
LINAC or telecobalt	OAR profiles	Dosimetric measures in standard phantom in TBI condition
LINAC or telecobalt	PDD or TPR	Dosimetric measures in standard phantom in TBI condition
Treatment planning system (TPS)	Dose in anthropomorhic phantom with lung type inhomogeneity: absolute values and dose distribution.	Dosimetric measures in TBI condition
In vivo dosimetry system	Entrance and exit dose and algorithm of calculation at half thickness	Dosimetric measures in TBI condition





…i.e. QA FOR TREATMENT MACHINE USING EPID



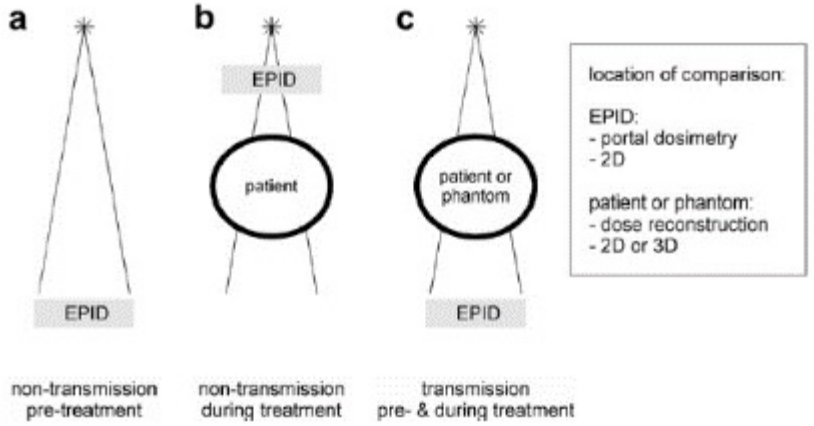


Table 2
List of key references on non-transmission based dose verification methods

Verification procedure	Type of verification	Key references	Objective of verification or subject of the study
QA of treatment machine	QA	Prisciandaro [93]	Radiation-light field congruence
	QA	Dirkx [52,53], Budgell [80,87]	Linac output, beam profile flatness and symmetry
	QA	Baker [84], Yang [95], Samant [96], Parent [97]	MLC leaf position for step-and-shoot fields
	QA	Vieira [86]	MLC leaf position and absolute output for low MU segmented fields
	QA	Vieira [98], Partridge [99], Chang [88]	MLC leaf position during dynamic treatment

How do you support a No-Coplanar beam using EPID/CBCT?
Why do we not support the transit dosimetry for those patients?

i.e. POTENTIAL QA AND ERROR DETECTED

Table 4
Overview of the various errors that can be detected with EPID dosimetry

Potential errors	Pre-treatment verification				Treatment verification			
	2D/3D	2D		3D	2D			3D
	No phantom	Behind phantom	Inside phantom	Inside phantom	Before patient	Behind patient	Inside patient	Inside patient
Machine								
Wedge presence and direction	Yes (systematic errors)				Yes (systematic and random errors)			
Presence of segment	Yes (systematic errors)				Yes (systematic and random errors)			
MLC leaf position/speed	Yes (systematic errors)				Yes (systematic and random errors)			
Leaf sequencing	Yes (systematic errors)				Yes (systematic and random errors)			
Collimator angle	Yes (systematic errors)				Yes (systematic and random errors)			
Beam flatness and symmetry	Yes (systematic errors)				Yes (systematic and random errors)			
Linac output during treatment	No				Yes			
Gantry angle	No	Possible	Possible	Possible	No	Possible	Possible	Possible
Plan								
Transmission through leaves	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Steep dose gradients	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
TPS modelling parameters for MLC	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Delivery of wrong patient plan	Yes (if same plan is used for verification and treatment)				Yes	Yes	Yes	Yes
Dose calculation in phantom or patient	No	No	Yes	Yes	No	No	Yes	Yes

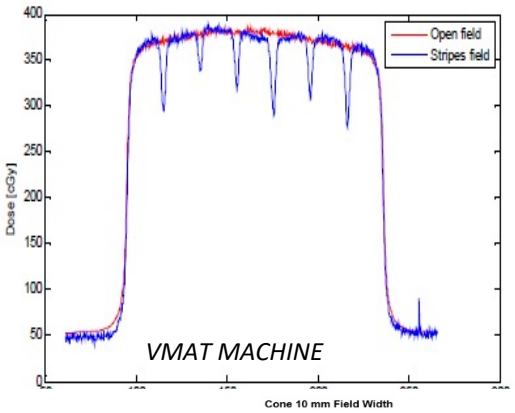
…DURING THE COMMISSIONING YOU NEED TO VERIFY THE TOLERANCE….
….. AND DEFINE THE FUTURE BASELINE

The NCS report has been downloaded on 29 Mar 2017

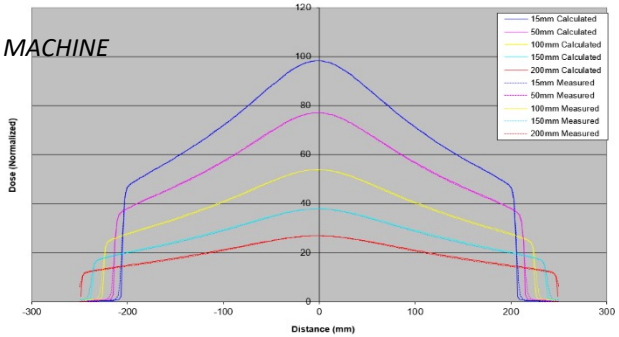
Code of Practice for the Quality Assurance and Control for Volumetric Modulated Arc Therapy

NEDERLANDSE COMMISSIE VOOR STRALINGSDOSIMETRIE

Report 24 of the Netherlands Commission on Radiation Dosimetry
February 2015

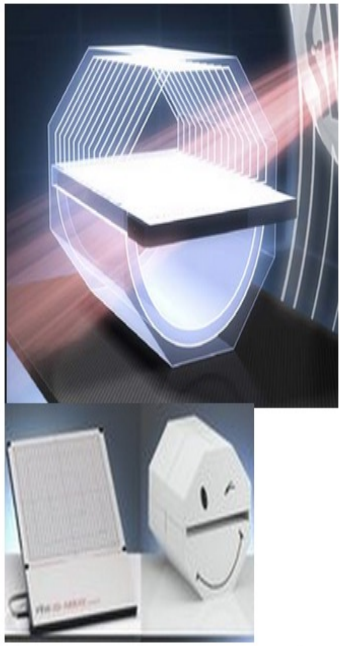


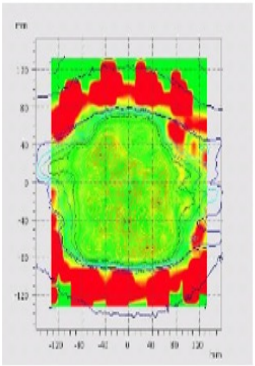
VMAT MACHINE

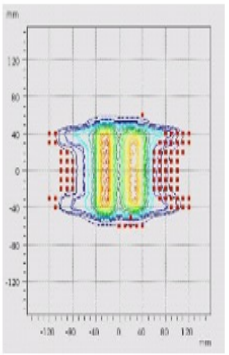


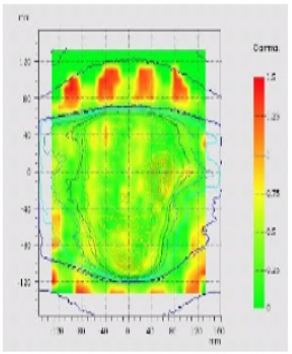
FFF MACHINE

Riepilogo misure eseguite con 2DArray in Solido (RW3) e Octavius							Local dose %	Selected dose %	Selected dose Dose prescriz. (Gy)
		TPS	Tecnica	Fantoccio	Piano	N°Fascio/Gantry Angle			
ID	Paziente								
	TG119HN	MONACO	IMRT	Octavius		11	97,7	100	0,33
	TG119HN	MONACO	IMRT	Octavius		12	94	98,7	0,29
	TG119HN	MONACO	IMRT	Octavius		13	95	98,6	0,22
	TG119HN	MONACO	IMRT	Octavius		14	99,2	100	0,45
	TG119HN	MONACO	IMRT	Octavius		15	89,4	89,4	0,28
	TG119HN	MONACO	IMRT	Octavius		16	91,5	99,2	0,53
	TG119HN	MONACO	IMRT	Octavius		17	89,5	92,3	0,13
	TG119HN	MONACO	IMRT	Octavius		18	87,7	98,1	0,30
	TG119HN	MONACO	IMRT	Octavius		19	90,1	97,5	0,38
	TG119HN	MONACO	IMRT	Octavius		ALL	97,8	81,6	2,91
	F……	MONACO	dMLC	RW3		1	100	100	2,43
	F……	MONACO	dMLC	RW3		2	100	100	2,09
	F……	MONACO	dMLC	RW3		3	100	100	3,27
	F……	MONACO	dMLC	RW3		4	95,5	100	2,21
	F……	MONACO	dMLC	RW3		5	100	100	3,88
	F……	MONACO	dMLC	RW3		6	98,5	100	2,29
	F……	MONACO	dMLC	RW3		7	100	100	1,67
	F……	MONACO	dMLC	RW3		8	100	100	2,90
	F……	MONACO	dMLC	RW3		9	98,9	100	1,69
	F……	MONACO	dMLC	RW3		ALL	99,1	100	22,42
	TG119 Cshape	MONACO	VMAT	RW3		41	64	63,7	0,16
	TG119 Cshape	MONACO	VMAT	RW3		42	78,9	79,6	0,14
	TG119 Cshape	MONACO	VMAT	RW3		43	75,9	92,7	0,16
	TG119 Cshape	MONACO	VMAT	RW3		ALL	66,1	67	0,45
	S……	MONACO	VMAT	RW3		31	80,6	98,6	0,79
	S……	MONACO	VMAT	RW3		32	85,8	96,9	0,75
	S……	MONACO	VMAT	RW3		ALL	83,9	95,8	1,53
	68229	MONACO	VMAT	Octavius		51	79,3	96,1	0,56
	68229	MONACO	VMAT	Octavius		52	72,5	90,2	0,56
	68229	MONACO	VMAT	Octavius		53	75,2	95	0,49





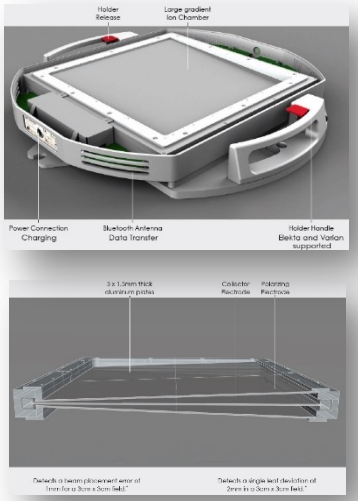


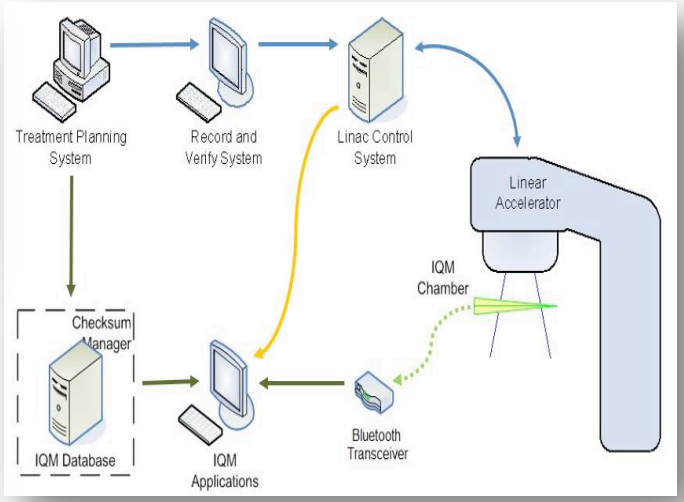


AGREEMENT TPS-PLAN-DELIVERY

What can happen if the instruments are not calibrated

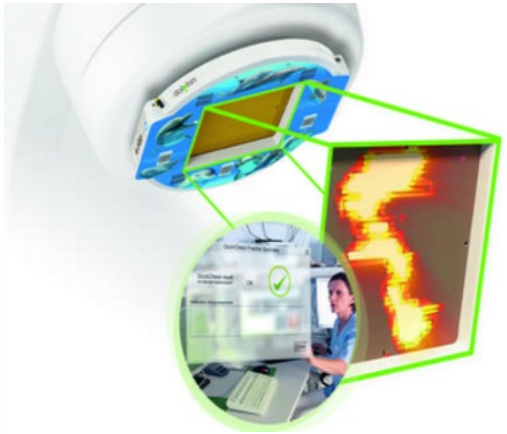
ALTERNATIVE - INDEPENDENT REAL-TIME BEAM MONITOR SYSTEM

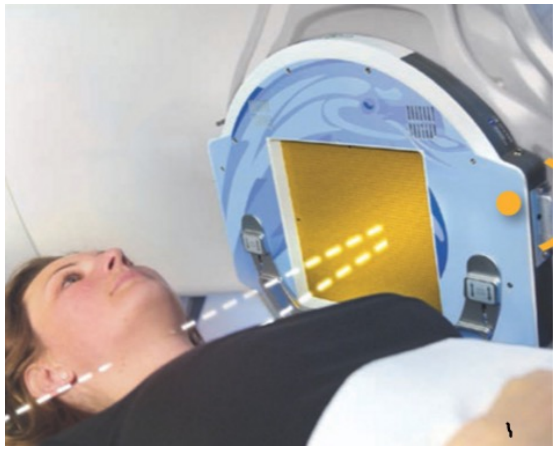




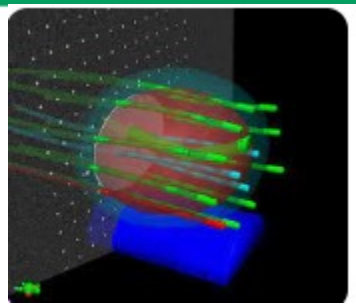
Courtesy of Andrew Jongho Jung Princess Margaret Cancer Centre (Toronto)

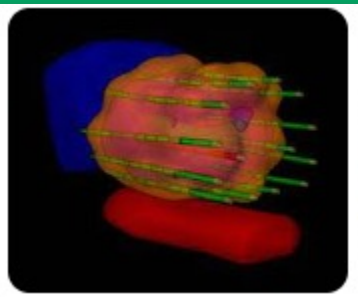
- *Possible QA of the LINAC*
- *Pre-Treatment QA activities*
- *Error prevention instead of error management*
- *Intra-fractional verification system*
- *Real-Time user interaction*
- *Automated monitoring of every single treatment fraction*
- *Patient delivery and safety improved in real-time*
- *In-Vivo evaluation*

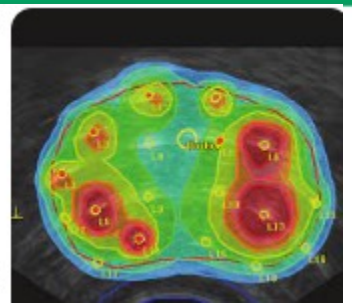


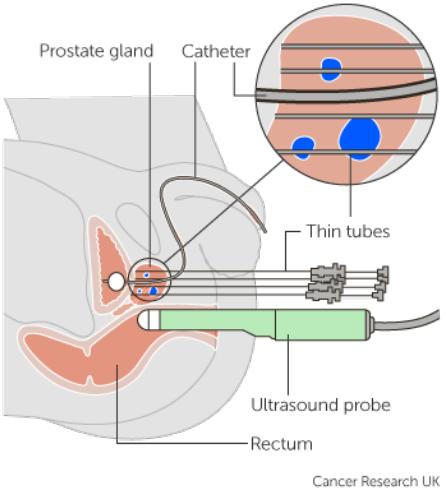


Brachytherapy QA

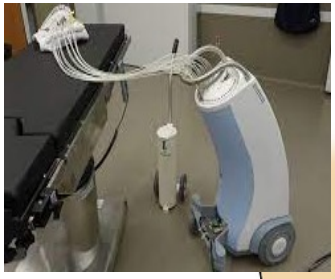








Cancer Research UK



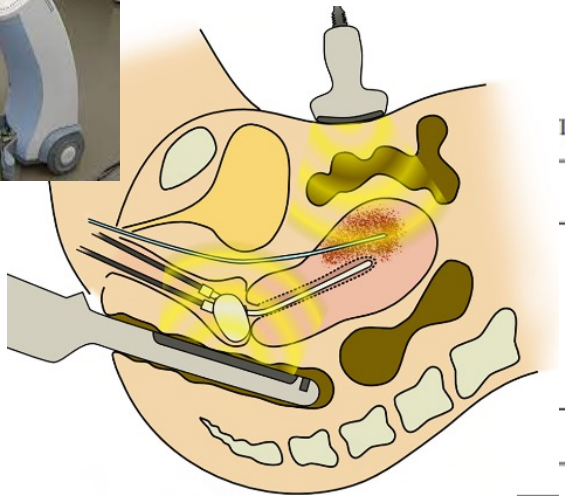


Table 1.1 Type and number of accidents reported in brachytherapy treatments (see IAEA 2000).

Accident caused by	*Number of cases*
Dose calculation error	6
Error in quantities and units	2
Incorrect source strength	7
Equipment failure	4
Other	13
Total	32

Brachytherapy QA

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PUBLICATIONS

WHAT DOES A **RETIRED** AAPM REPORT MEAN?

Search for a report: Brachytherapy submit | Show All | Show All Tabular | Explore by committee?

Report 377.B TG377	2024	AAPM BTSC Report 377.B: Physicist brachytherapy training in 2022 – A survey of therapeutic medical physics residents 'Brachytherapy' found in Title, Summary, Committee/Notes, Keywords
Report 267 TG267	2024	AAPM Task Group Report 267: A joint AAPM GEC-ESTRO report on biophysical models and tools for the planning and evaluation of brachytherapy 'Brachytherapy' found in Title, Summary, Committee/Notes, Keywords
Report 372 WGDCAB	2023	AAPM WGDCAB Report 372: A joint AAPM, ESTRO, ABG, and ABS report on commissioning of model-based dose calculation algorithms in brachytherapy 'Brachytherapy' found in Title, Summary, Committee/Notes, Keywords
Report 377 TG377	2023	AAPM BTSC Report 377: Physicist Brachytherapy Training in 2021—A survey of therapeutic medical physics residency program directors 'Brachytherapy' found in Title, Committee/Notes, Keywords
Report 303 TG303	2022	AAPM task group report 303 endorsed by the ABS: MRI implementation in HDR brachytherapy—Considerations from simulation to treatment 'Brachytherapy' found in Title, Summary, Committee/Notes, Keywords

Quality Control of Brachytherapy Equipment, 2004 (ESTRO)

ESTRO

Description	*Minimum requirements*	
	Test frequency	Action level
Safety systems		
Warning lights	daily/3M*	-
Room monitor	daily/3M*	-
Communication equipment	daily/3M*	-
Emergency stop	3M	-
Treatment interrupt	3M	-
Door interlock	3M	-
Power loss	3M	-
Applicator and catheter attachment	6M	-
Obstructed catheter	3M	-
Integrity of transfer tubes and applicators	3M	-
Timer termination	daily	-
Contamination test	A	-
Leakage radiation	A	-
Emergency equipment (forceps, emergency safe, survey meter)	daily/3M*	-
Practising emergency procedures	A	-
Hand crank functioning	A	-
Hand held monitor	3M/A**	-
Physical parameters		
Source calibration	SE	>5 %
Source position	daily/3M*	>2 mm
Length of treatment tubes	A	>1 mm
Irradiation timer	A	>1 %
Date, time and source strength in treatment unit	daily	-
Transit time effect	A	-

CONCEPT – Take Home Messages

Expert Brainstorming- Multiple-criteria decision

Decision Maker

Wrong Workflow or Healthcare Model – Error investigation

Results: Simplify and prevent accident

Take Home Messages

Organization of the Quality System in Radiotherapy

- **Vision of the process and service provided**
- **Codified structure and responsibility**
- **Documentary collection, training and performance monitoring**
- **Detail of the operating instructions**
- **Sustainable and viable organizational models**
- **Improvement actions, Audits and Reviews**
- **Awareness of the quality of work and information support available**

Risks of miss-interpretation of QA Programme

- ***Implementation and description of impractical or unsustainable processes***
- ***Detailed but unreliable walkthrough description (Review)***
- ***Inconsistency between «Best-Practice» and «Clinical-Practice»***
- ***Useless production of documents with staff repulsion to correct use***
- ***Lack of awareness of the quality of work***

SERVIZIO SANITARIO REGIONALE
EMILIA-ROMAGNA
Azienda Ospedaliero - Universitaria di Modena

“That’s too much!!!”

(Praha 2009)