UNIVERSITAS INDONESIA

FAKULTAS MATEMATIKA DAN ILMU PENGETAHUAN ALAM

Dosimetry Audit in Radiotherapy

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DEPARTEMENT OF PHYSICS FMNS UNIVERSITAS INDONESIA

Outline

- Quality Audit
- IAEA experience in dose Audit RT
- RPC MD Anderson experience
- Australian Study
- FNCA Study
- Malaysian Study
- Indonesian Study
- Conclusion

Quality Audit

Definition :

- a systematic and independent examination to determine whether or not quality activities and results comply with planned arrangements and
- whether or not the arrangements are implemented effectively and
- are suitable to achieve the stated objectives.

Quality Audit Parameters

- Can be conducted for internal or external purposes.
- Can be applied at any level of a QA program.
- Are performed by personnel not directly responsible for the areas being audited, however in cooperative discussion with the responsible personnel.
- Must be against pre-determined standards, linked to those that the QA program is trying to achieve.
- Evaluate the need for improvement or corrective action if those standards are not met.

Podgorsak (2005)

Quality in RT

- How is it done??
- Local expertise
- National/international guidance
- Calibration CoP
- QA guidance

Courtesy of Clark

Where might the discrepancies lie? (FMEA)

- Calibration
- TPS model eg TMR/PDD, OAF, OF, small fields
- TPS algorithm eg high/low density
- Incorrect MU
- Linac isocentre
- TPS isocentre
- Set up
- QA issues eg flatness/symmetry/energy

- Ouput eg gantry/dose rate
- MLC positions/sequences
- Couch/other attenuation
- CT density to HU / heterogeneities…..

Med Phys. 2016 Jul; 43(7): 4209–4262. PMCID: PMC4985013
Published online 2016 Jun 15. doi: 10.1118/1.4947547 PMID: 27370140

The report of Task Group 100 of the AAPM: Application of risk analysis methods to radiation therapy quality management

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Inherent limitations to TPS accuracy

- Pencil beam algorithms not accurate in heterogeneous anatomy
  - ✓Banned from north American clinical trials for more than a decade
- Even modern algorithms not perfect
- Not accurate near metal interfaces or at surface
- Errors even present for dose calculation in/through lung
  - ✓3.7% overestimation of dose for S/C algorithms in island lung tumors
  - ✓ Kry et al, IJROBP 2013
- 3% error beyond lung associated with AAA
  - ✓Dunn et al, Physica Medica 2015
- Small field conditions
  - ✓7+% errors for 10mm MLC gap because tongue and groove not well modeled
  - ✓Hernandez et al, PMB 2017

Courtesy of Clark

Suboptimal commissioning

- Reference output between TPS and linac must match
  - ✓ Possible to enter reference incorrectly into TPS
  - ✓ Means linac must be correctly calibrated
- Basic dosimetric data must be correct
  - ✓ PDD, OF, etc. for TPS and linac must match
  - ✓ Choices are made about how good match is
- Non-dosimetry parameters must be correct
  - ✓ MLC, source terms, etc in TPS must describe linac
- How well are these steps done in current radiotherapy?
- How much does this affect clinical dose delivery

Courtesy of Clark

Radiotherapy dosimetry audit

Dosimetry audit plays an important role in the development and safety of radiotherapy

A number of classification systems have been proposed for different audit types, generally based on the level of complexity.

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Br J Radiol. November 2015; 88(1055): 20150251. PMCID: PMC4743452
Published online 2015 Sep 28. PMID: 26329469
doi: 10.1259/bjr.20150251

Radiotherapy dosimetry audit: three decades of improving standards and accuracy in UK clinical practice and trials

Catharine H Clark, PhD,[1,2] Edwin GA Aird, PhD,[3] Steve Bolton, MSc,[4,5] Elizabeth A Miles, MPhil,[3] Andrew Nisbet, PhD,[1,6] Julia AD Snaith, MSc,[2] Russell AS Thomas, MSc,[2] Karen Venables, PhD,[3] and David I Thwaites, PhD[7]

Author information ▸ Article notes ▸ Copyright and License information
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Corresponding author.

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4743452/

Dosimetry level	ACDS	Detector type	Mode	System checked	Comments
Level I	Output under reference conditions	TLD, OSL	Remote	Every radiation beam	Identical to RPC audit
Level IB	Output under reference conditions	Ionization chamber	On-site	Every radiation beam	Offered to new centres prior to opening
Level II	Dose distribution in physical phantoms	Detector array	Remote	Planning system	Can include homogeneity and allows clarification of Level III findings
Level III	Anthropomorphic phantom end to end	Ion chamber, radiochromic film	On-site	Entire treatment chain	Treatment specific—most relevant for clinical trials

Why is dosimetry audit useful?

- Important role in the development and safety of radiotherapy
- Helps reduce delivered dose variability both nationally and in many multiinstitutional trials (often mandatory)
- Financial incentives: if you can’t prove you are safe and accurate you may not
- be engaged to provide radiotherapy
- National and large scale audits are able to set, maintain and improve
- standards, as well as having the potential to identify issues which may cause
- harm to patients, thus improving quality

Courtesy of Clark

What is the impact of dosimetry audit?

- Issues identified (with sufficient data)
- Knowledge of what is best from equipment
- Confidence in (new) techniques
- Leading to:
  - Consistency
  - Reduced variability
  - Raised standards
  - Increased quality

Courtesy of Clark

How dosimetry audit supports best practice

- Implementation of novel and complex techniques
- Provides independent check of local approaches
- Facilitates awareness and understanding of issues which may exist
- Shares experience
- Benchmarks centres with similar equipment
- Increases knowledge of what is achievable

Courtesy of Clark

How to maximise the impact of audit?

- Consider issues are most likely to occur or introduce the largest errors and design the audit to address these
- What are the best approaches to multicentre audit: remote audit vs site visit?
- Collect local data?
- For new technologies do we need end-to-end tests or specific tests for specific goals – can we assume that the holistic approach is correct i.e. all's well that ends well?
- How does the audit and the tolerances used impact on patient clinical outcome?

Courtesy of Clark

Global dosimetry audit services

International

- **IAEA / WHO**
  - 140 Countries
- **IROC**
  - North America
  - >15000 beams per year
  - 60 countries
  - Complex treatments
- **EQUAL ESTRO**
  - 40 countries
  - EU region
  - >800 beams per year

National

- UK
- Japan
- Australia
- Brazil
- EU
  - Belgium,
  - Czech Republic
  - Finland,
  - France,
  - Greece,
  - Germany,
  - Switzerland,
  - Netherlands,
  - Norway,
  - Poland,
  - Slovakia.

Clinical Trial QA

- EORTC
- IROC
- JCOG
- RTTQA
- TROG

- Collaboration
- Harmonization of Trial QA
- Improve QA in RT

J. Izewska et al, *Physics and Imaging in Radiation Oncology, 2018.*.

IAEA methodology for dosimetry audits

1

Remote audits (TLD/RPLD, film)

On-site audits (IC, film)

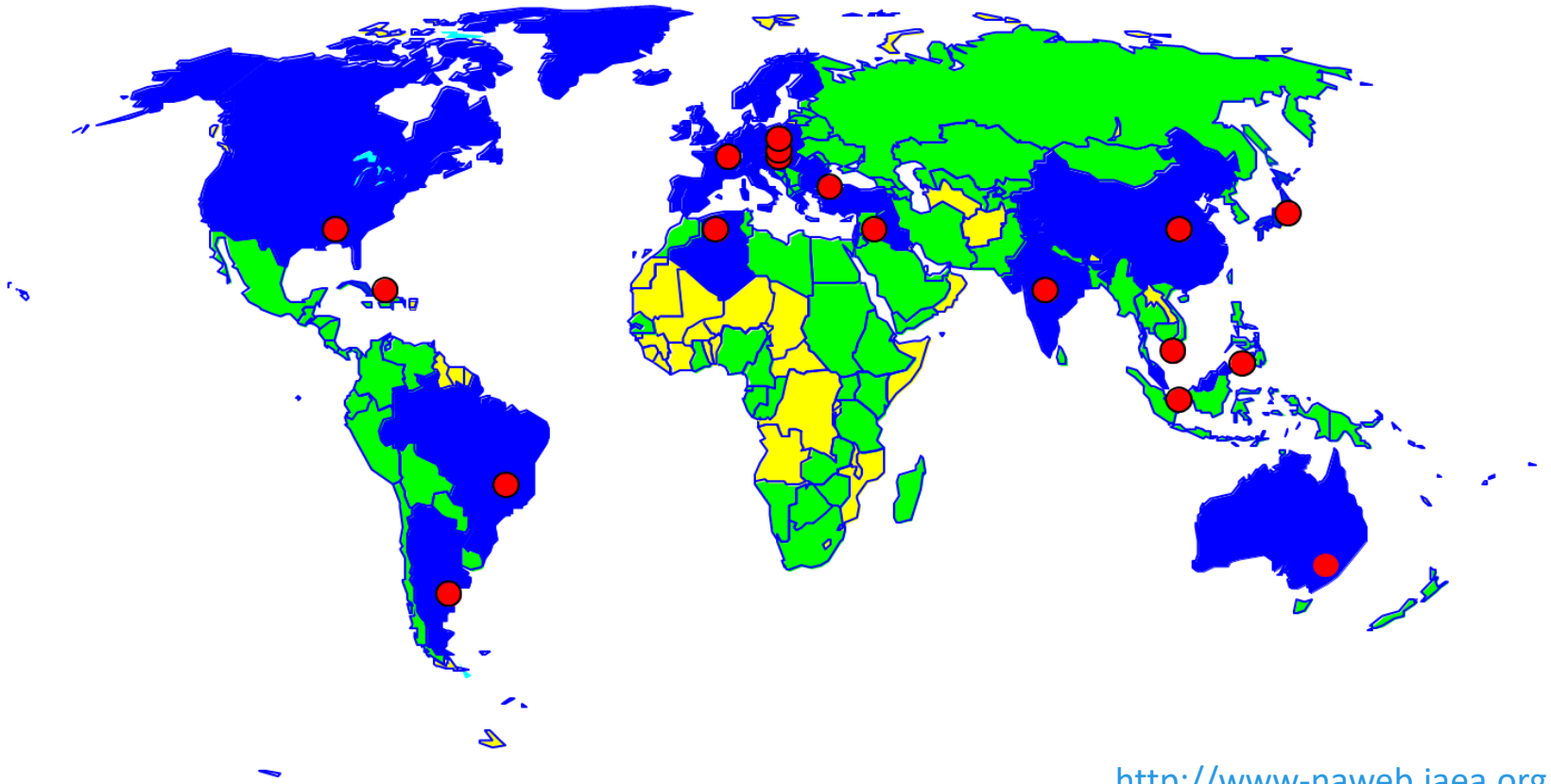
Reference dosimetry, beam parameters and end-to-end audits

Joanna et.al.

https://humanhealth.iaea.org/HHW/RadiationOncology/ICARO2/

IAEA's Postal Dosimetry Audit

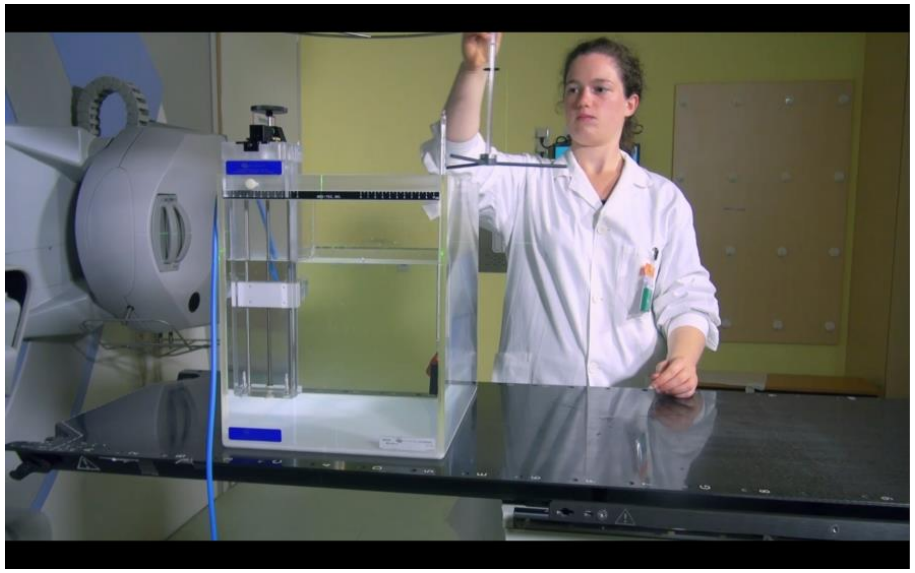
The importance of an independent dosimetry audit in radiotherapy was recognized by the IAEA as long ago as 1969 when, in collaboration with the World Health Organization (WHO), the postal dosimetry audit programme was initiated.



http://www-naweb.iaea.org/nahu/DMRP/tld.html

IAEA'S POSTAL DOSIMETRY AUDIT

On request, and with approval, the IAEA will send you a number of TLD capsules, together with appropriate holders and detailed instructions for use to a participating centre.

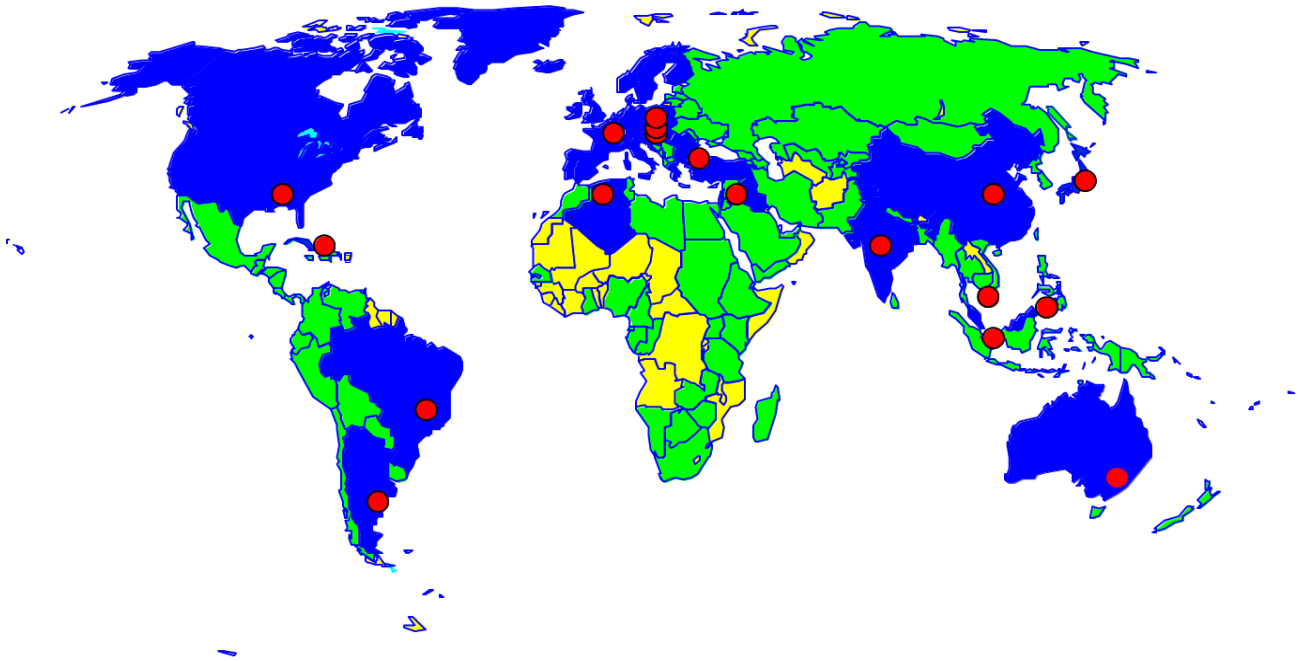


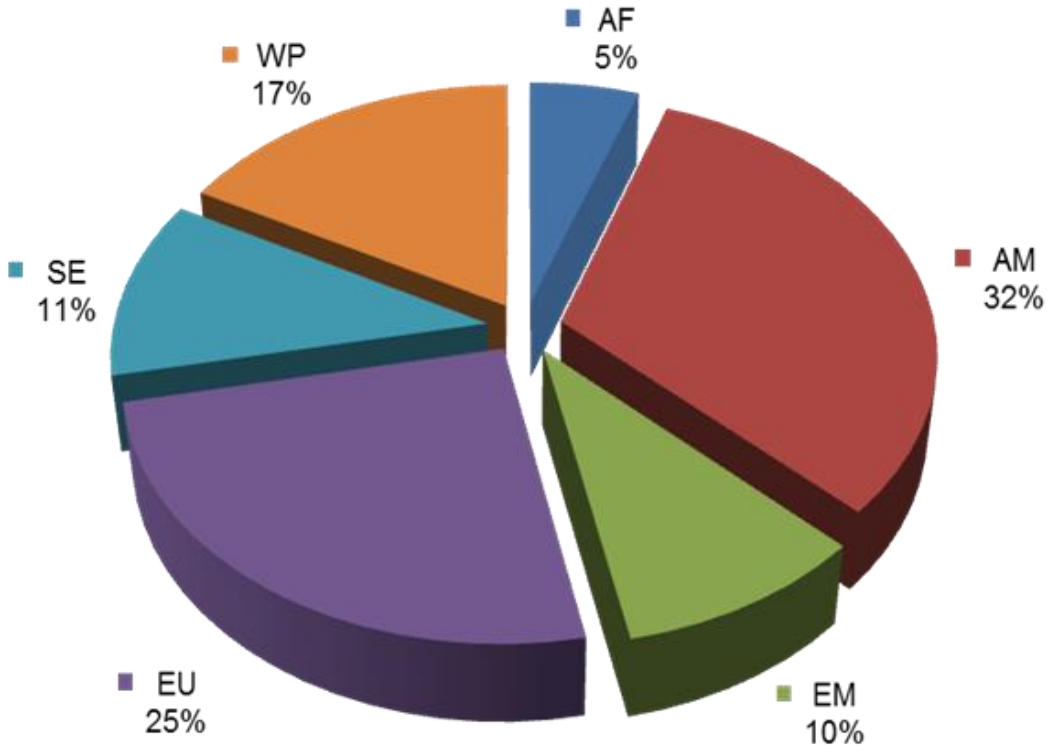
http://www-naweb.iaea.org/nahu/DMRP/tldforms.html#video

IAEA'S POSTAL DOSIMETRY AUDIT (2016)

How many centres participate in this programme?

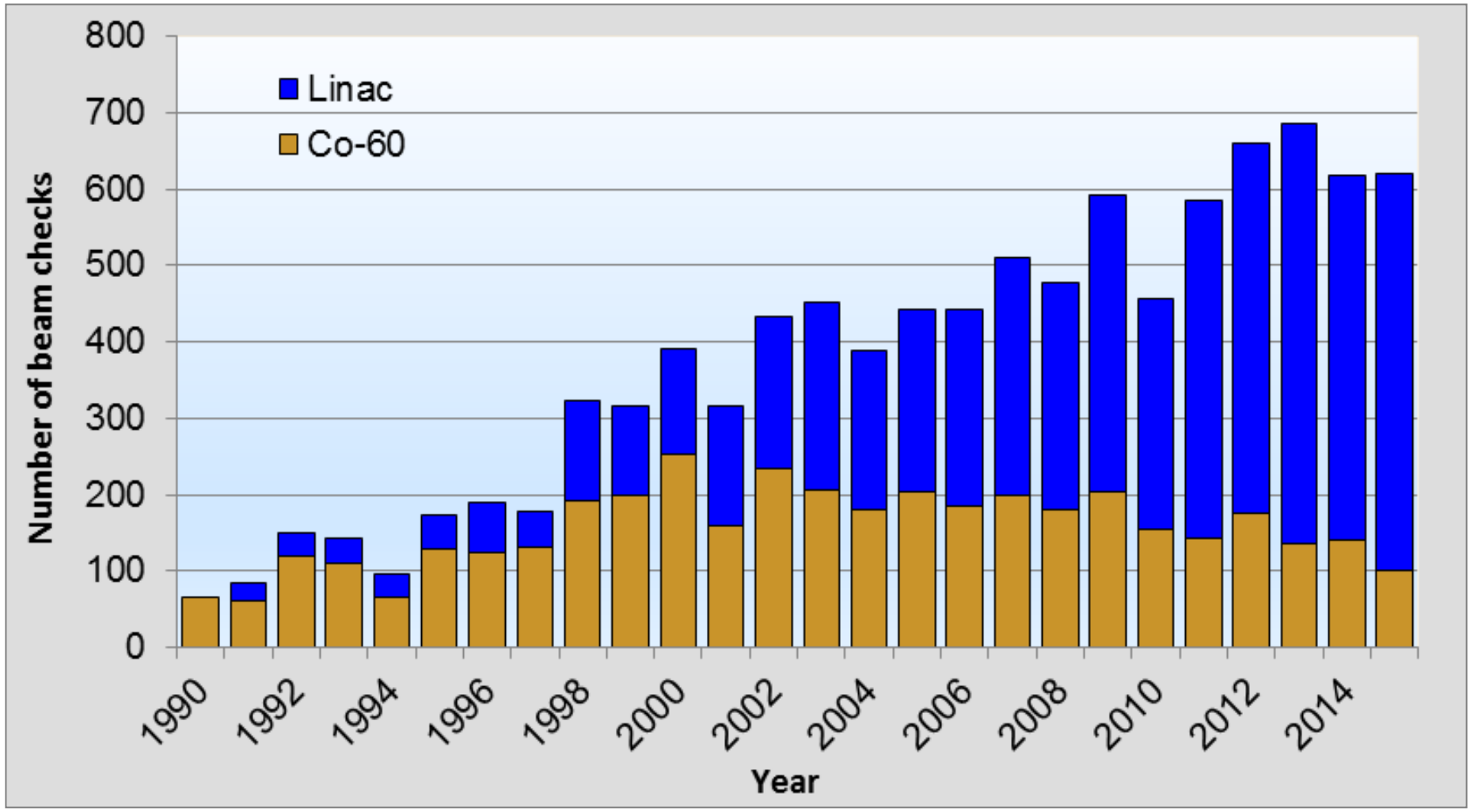
Since 1969 the IAEA Dosimetry Laboratory has provided dosimetry audits to 2,200 radiotherapy centres in 132 countries. This required 11,500 sets of TLDs.

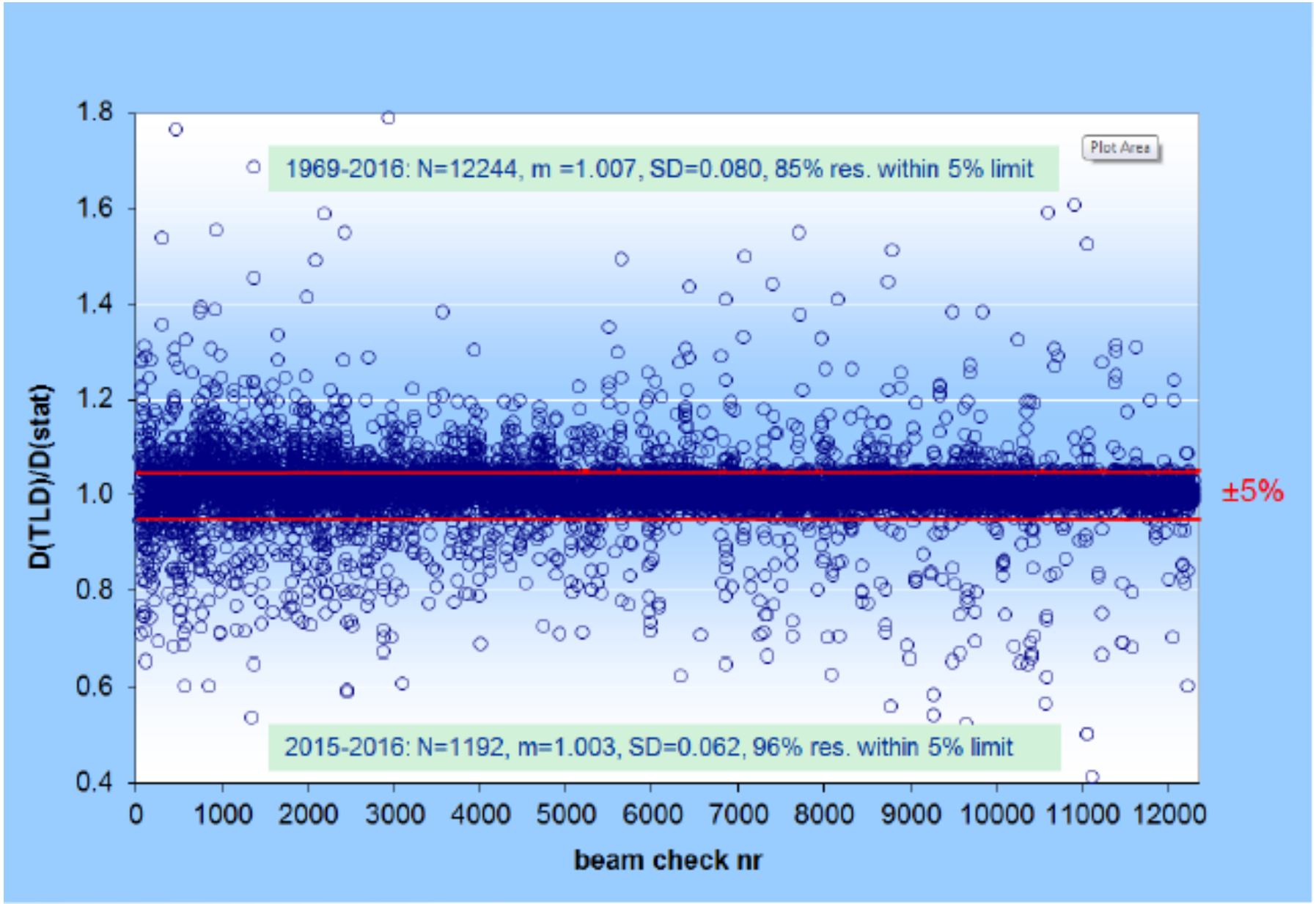




IAEA'S POSTAL DOSIMETRY AUDIT

And how many beams are checked?





Currently >95% of the results are within 5% acceptance limit

Joanna et.al.

Some Developments

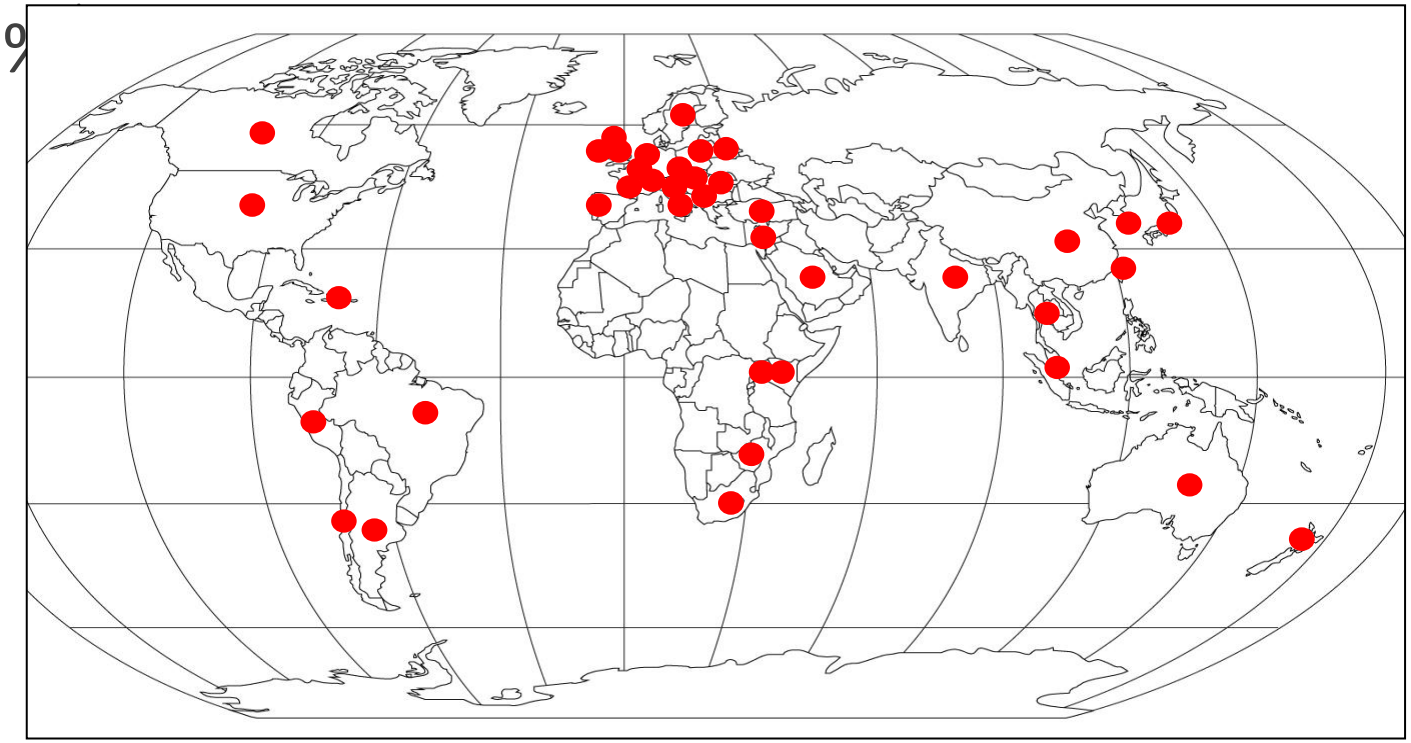
IAEA organized some projects in Dosimetry Audit

- Remote Audit Small Field (Algeria, Brazil, China, Cuba, Czech Rep., India, Poland, Thailand; Austria, Belgium, Finland, Sweden, UK, USA)
- Remote Audit in IMRT
- Dosimetry Audit in Brachytherapy (New)

IAEA support TPS Audit in Europe

RPC 2 MD Anderson Experiences (2011)

Monitoring 1888 inst. participating in clinical trials -
includes 210 non-North American sites
41 countries (since 2006 45%
~23,000 beams
- ~3500 machines



David Followill et al.

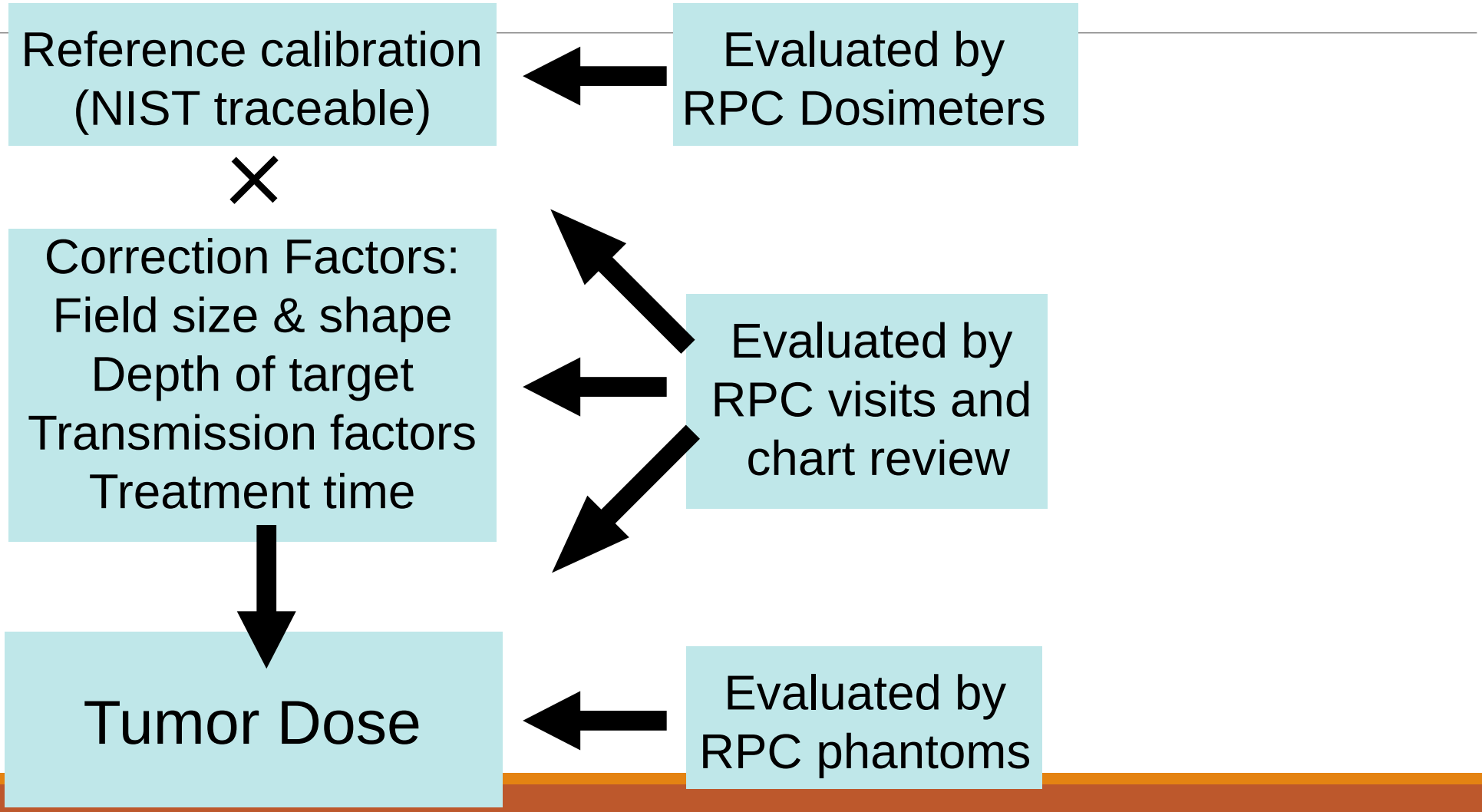
https://iroc.mdanderson.org/RPC/Publications/RPC_Presentations/2016

RPC MD Anderson
Radiological Physics Center

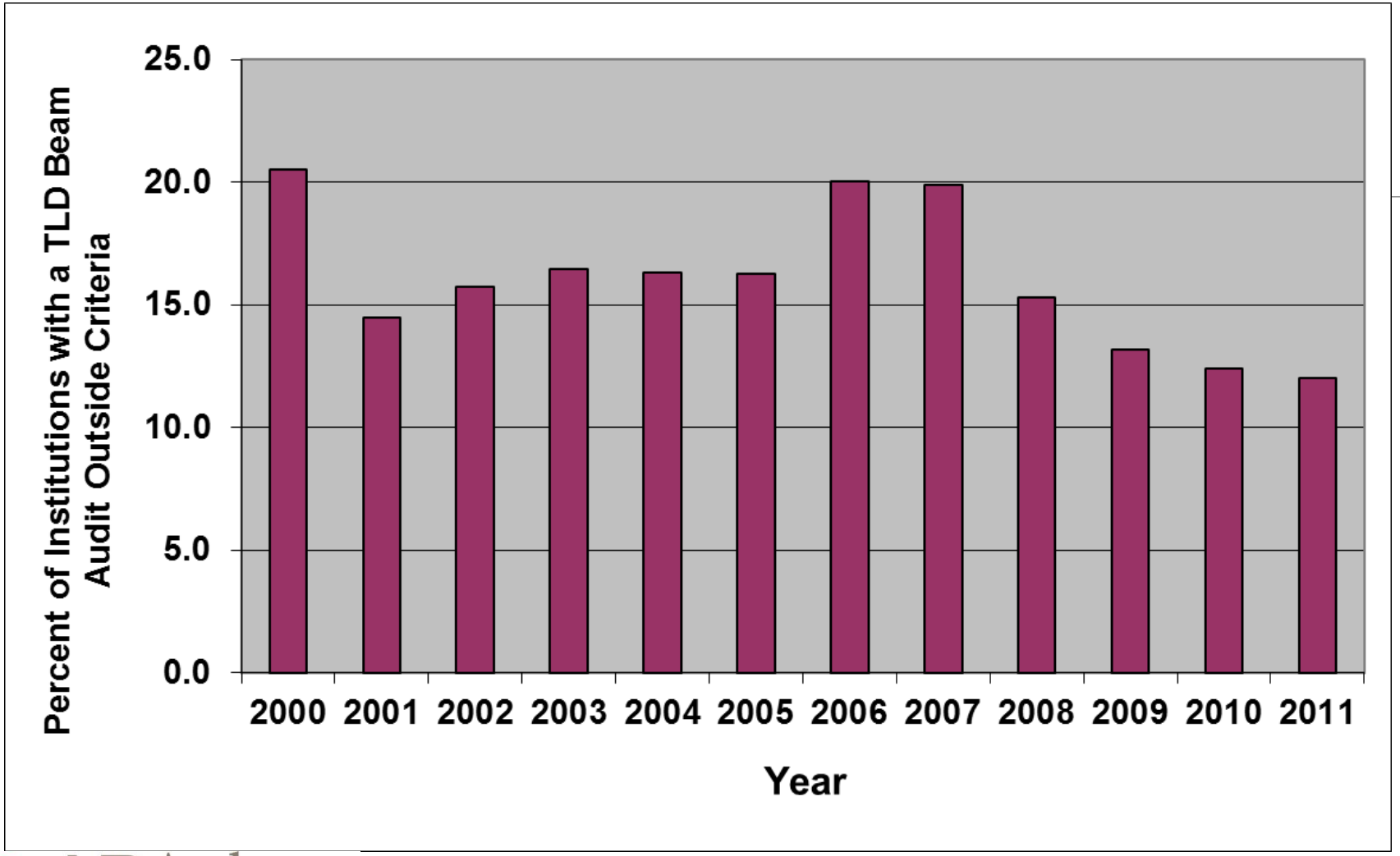
Components of RPC QA Program

1. Remote audits of machine output
   1,888 institutions, ~**14,000** beams measured with TLD and OSLD in North America and Internationally
2. Patient Treatment record reviews
   474 charts reviewed for GOG, NSABP, NCCTG, RTOG (brachytherapy)
3. On-site dosimetry reviews
   41 institutions visited in 2011
   (~150 accelerators/450 beams measured)
4. Credentialing - Phantoms
   ~**500** irradiations in 2011

RPC Verification of Institutions' Delivery of Tumor Dose



OSLD/TLD Beam Output Checks



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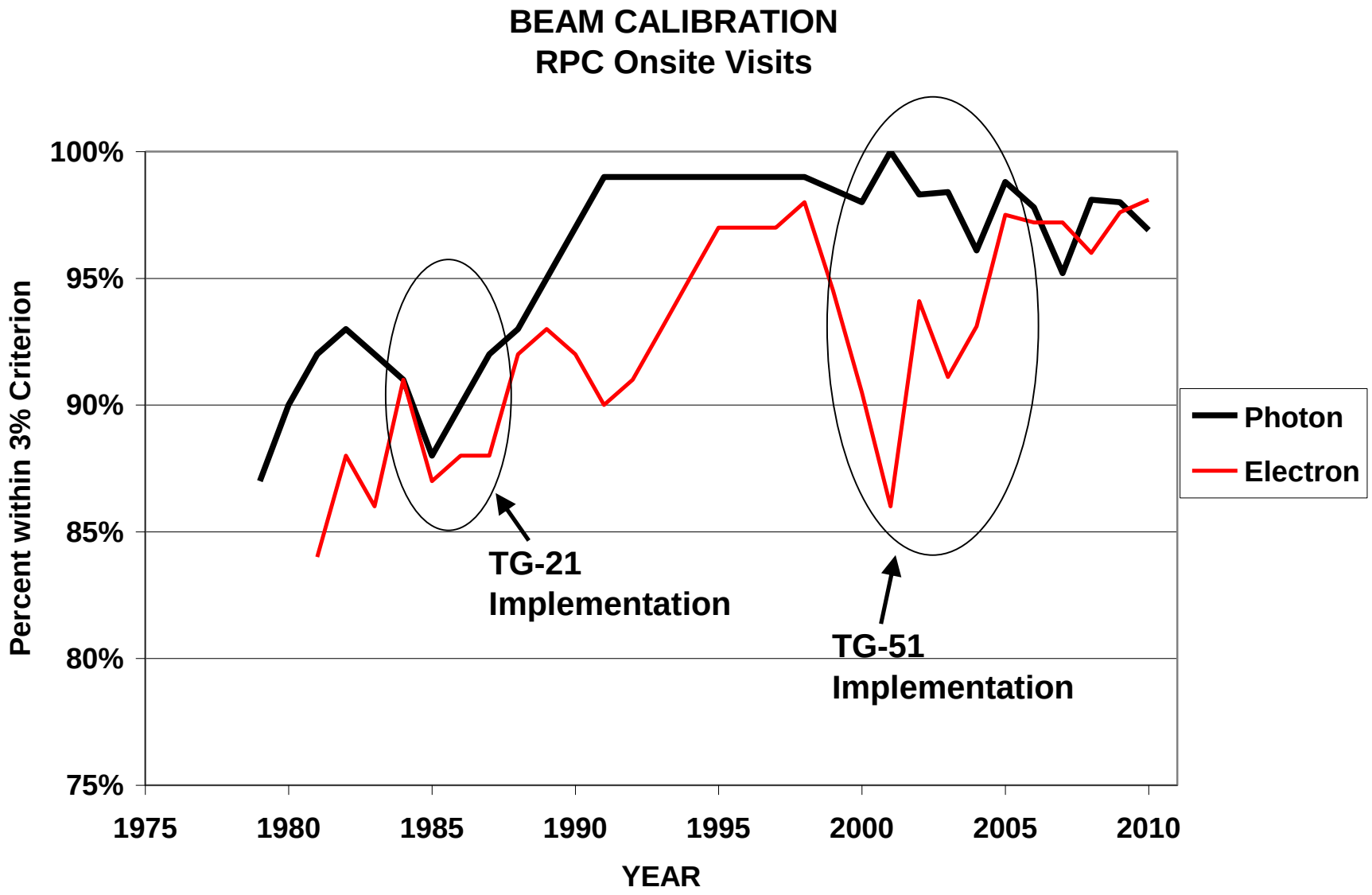
3-4% of the beams require a repeat

Comprehensive On-Site Audits



RPC MD Anderson
Radiological Physics Center

3 FNCA Study

Multicentre dose audit for clinical trials of radiation therapy in Asia

Hideyuki Mizuno[1*], Shigekazu Fukuda[1], Akifumi Fukumura[1], Yuzuru-Kutsutani Nakamura[1], Cao Jianping[2], Chul-Koo Cho[3], Nana Supriana[4], To Anh Dung[5], Miriam Joy Calaguas[6], C.R. Beena Devi[7], Yaowalak Chansilpa[8], Parvin Akhter Banu[9], Masooma Riaz[10], Surya Esentayeva[11], Shingo Kato[12], Kumiko Karasawa[13] and Hirohiko Tsujii[1]

https://www.fnca.mext.go.jp/english/mu/e_papers.html

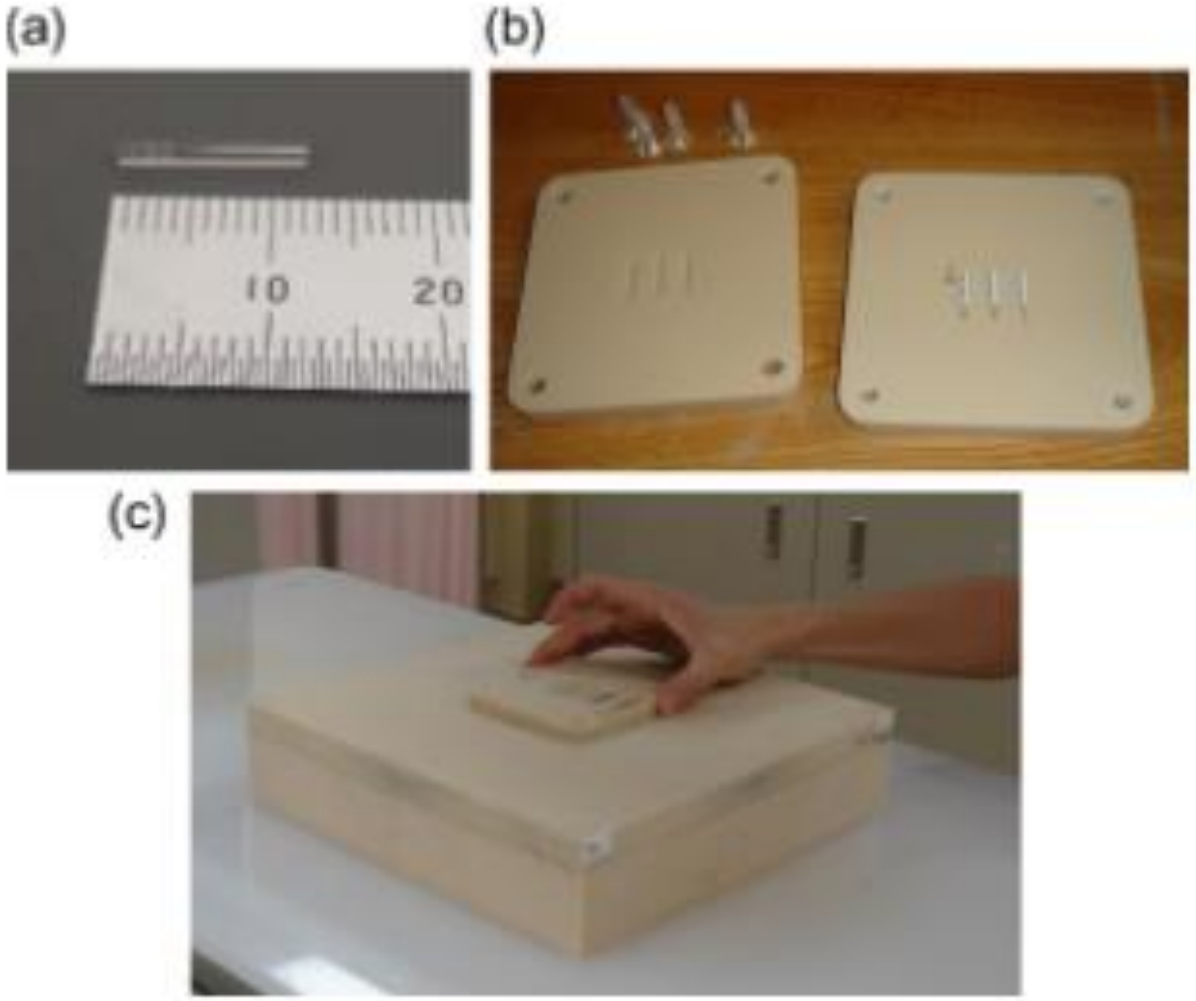


Fig. 1. (a) RGD element with ID number '100'. (b) Central part of a solid phantom containing 3 RGD elements. The interval between each element is 1 cm. (c) The central part of the solid phantom is inserted in the 30 × 30 cm solid phantom to irradiate the RGDs at reference conditions.

FNCA Study

Multicentre dose audit for clinical trials of radiation therapy in Asia

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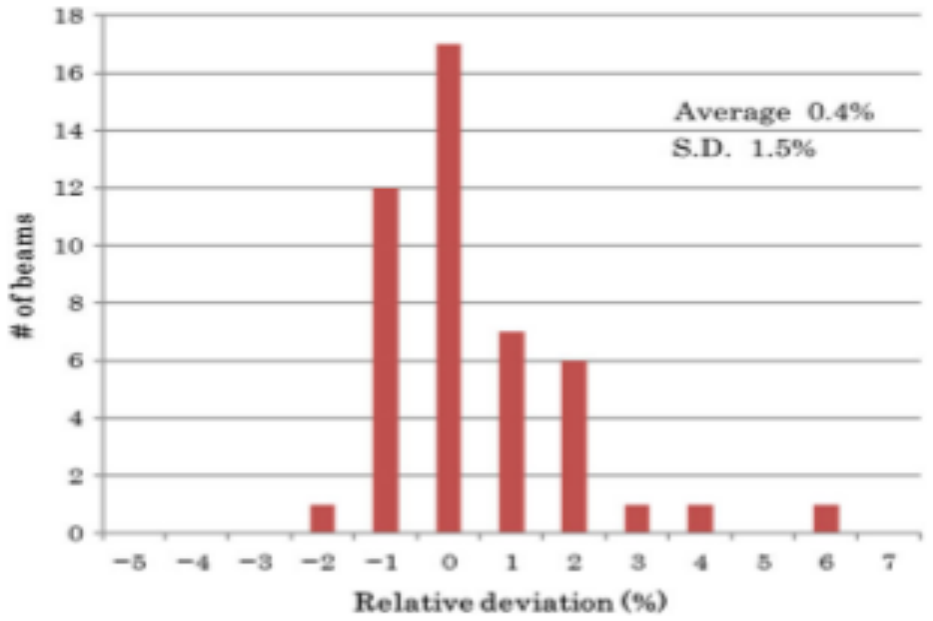
Table 2. Summary of the results of the dose audit

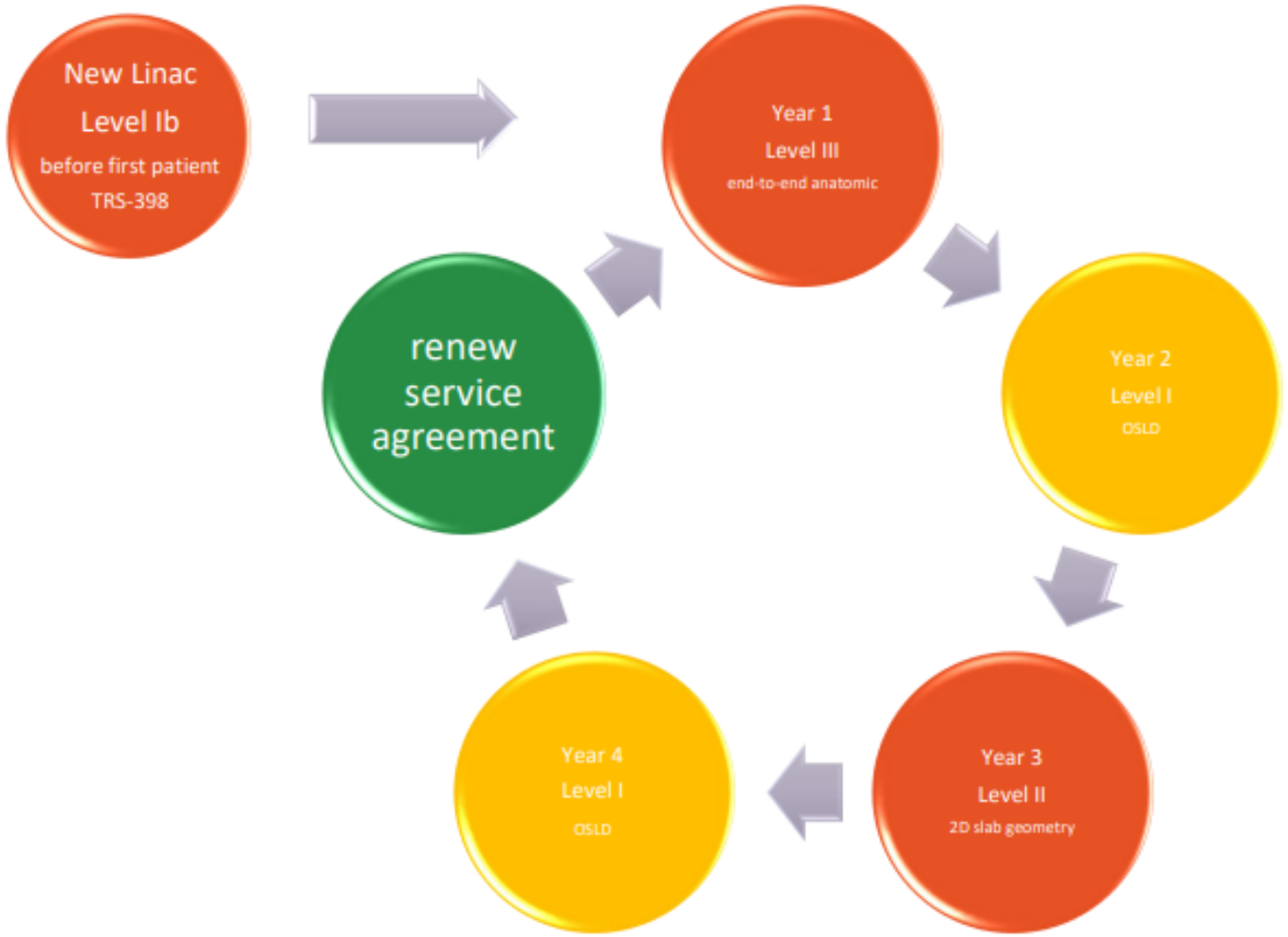
Beam energy	Number of beams	Average deviation	S.D. of the deviation
4 MV	1	−1.2%	
6 MV	22	+ 0.4% (−1.6 to +3.5%)	1.4%
10 MV	11	+ 1.0%* (−1.4% to +6.1%)	2.0%
15 MV	9	−0.1% (−1.0 to +1.4%)	0.8%
18 MV	3	+ 1.0% (+0.1 to +1.5%)	0.8%
Total	46	+0.4%	1.5%

*The average deviation of the 10 MV beams is reduced to +0.4% if the beam with the largest deviation (+6.1%) is excluded. The results were categorized according to their beam energies.



3

ACDS Audit Program Overview



ON SITE

MAIL OUT

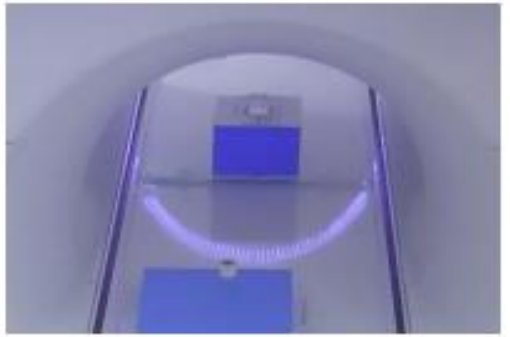
- 4-year audit cycle
- Fee for service
- Full cost recovery
- Not subsidised

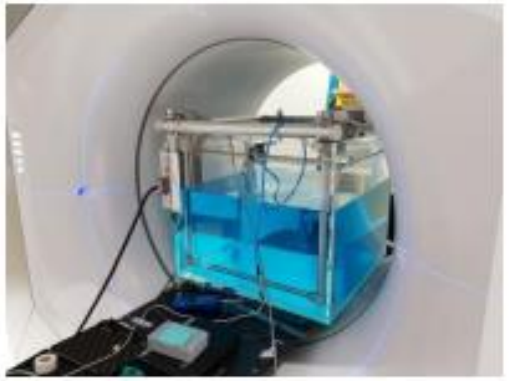
Field Trials
additional
no fee

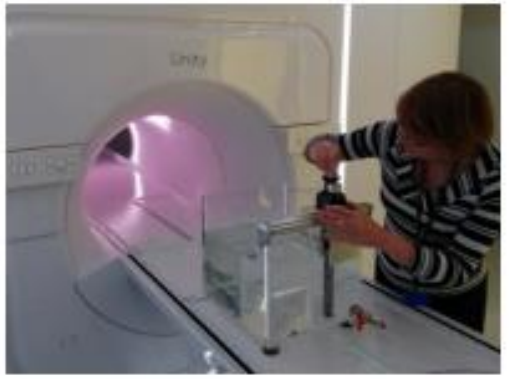
Courtesy of Andrew

Level I

- Level I
  - OSLD mailout
  - IROC MoU of equivalence
- Level Ib
  - Dose to water
    - TRS-398
    - Farmer® PTW 30013 photons
    - Roos® PTW 34001 electrons
  - Small field output factors
    - TRS-483
    - microDiamond PTW 60019





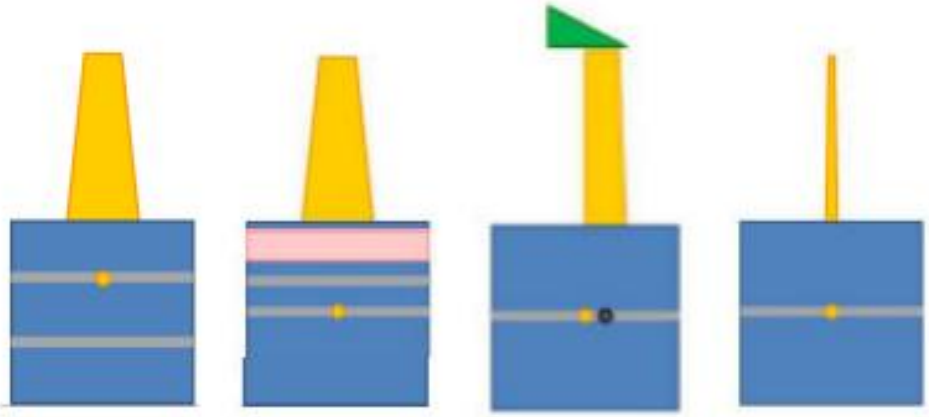


Courtesy of Andrew

Level II

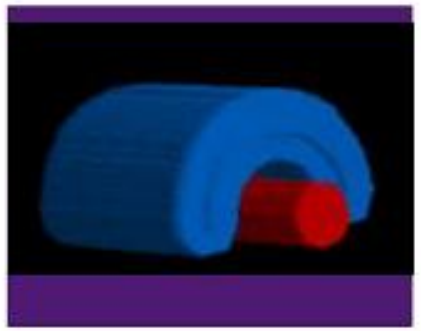
3DCRT

10 Cases, Gantry 0



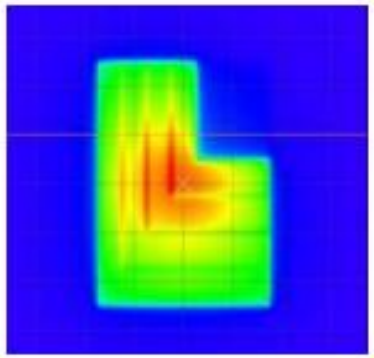
- 2D measurement single plane
  - CIRS Plastic Water®
  - Lung equivalent insert (5 cm)
  - PTW OCTAVIUS® 1500^{MR}

IMRT and VMAT

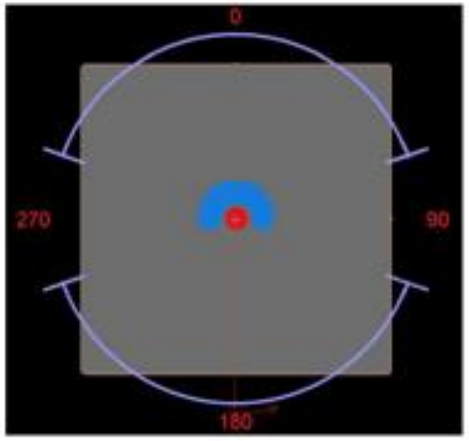


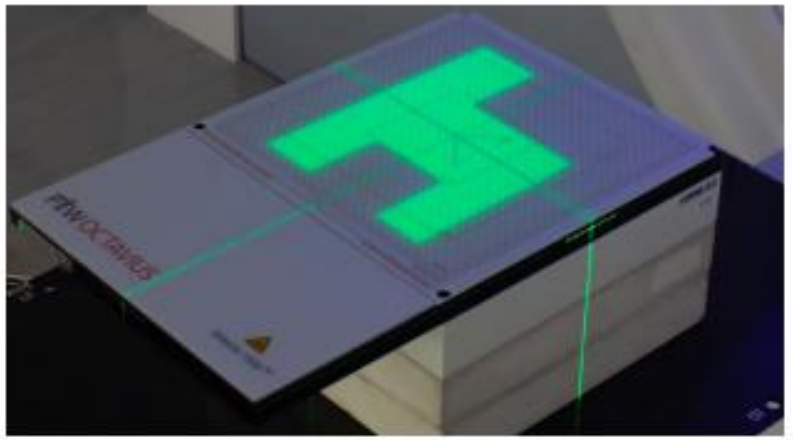
"C Shape"
TG119 test shape
With/without lung

"Chair"
Van Esch et al.
Sliding window



"Four L"
4 nested L shapes
Static delivery

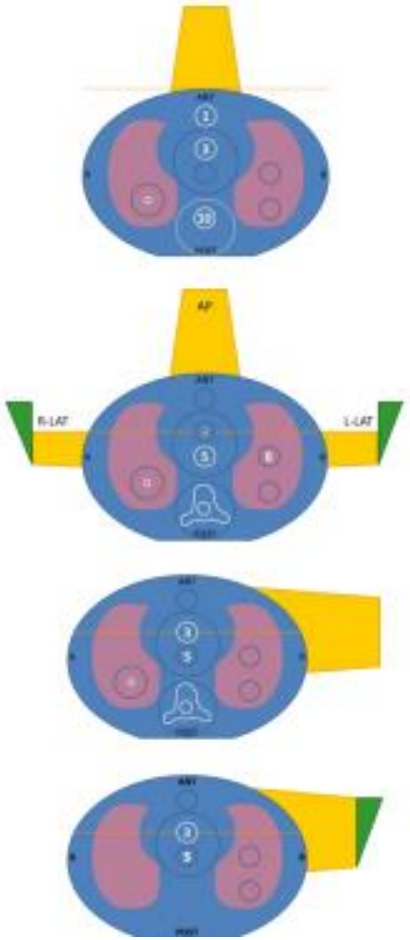


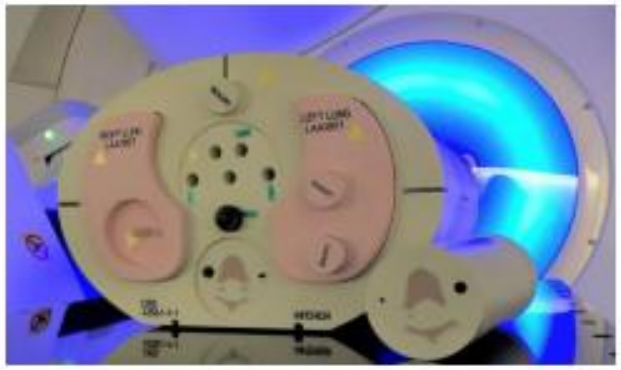


Courtesy of Andrew

Level III

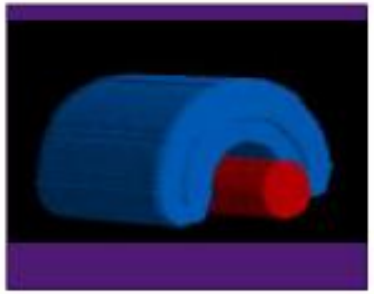
3DCRT



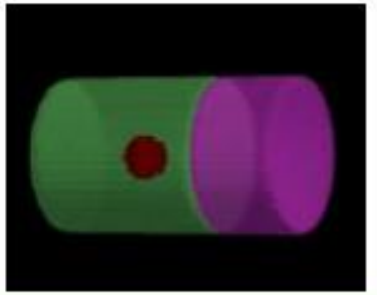


- CIRS thorax phantom (Anne)
- Lung & Bone equivalent inserts
- PTW 30013 (3DCRT)
- IBA CC13 (IMRT/VMAT)
- Gafchromic™ EBT-3 (SABR)
- PTW 60019 (SABR)

IMRT and VMAT

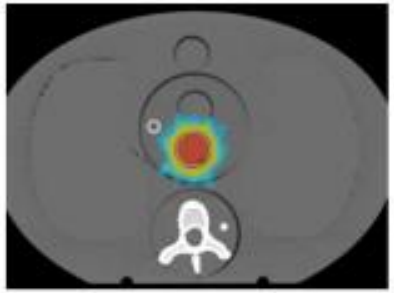


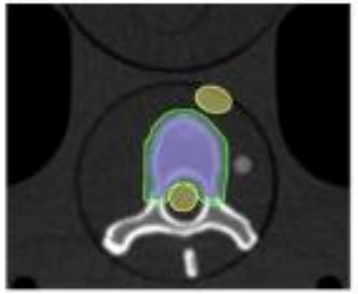
"C Shape"
TG119 test shape
With/without lung

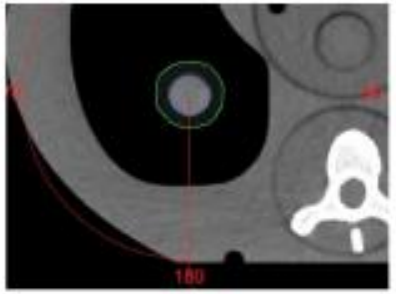


"Complex Case"
2 adjoining PTVs
With lung

SABR



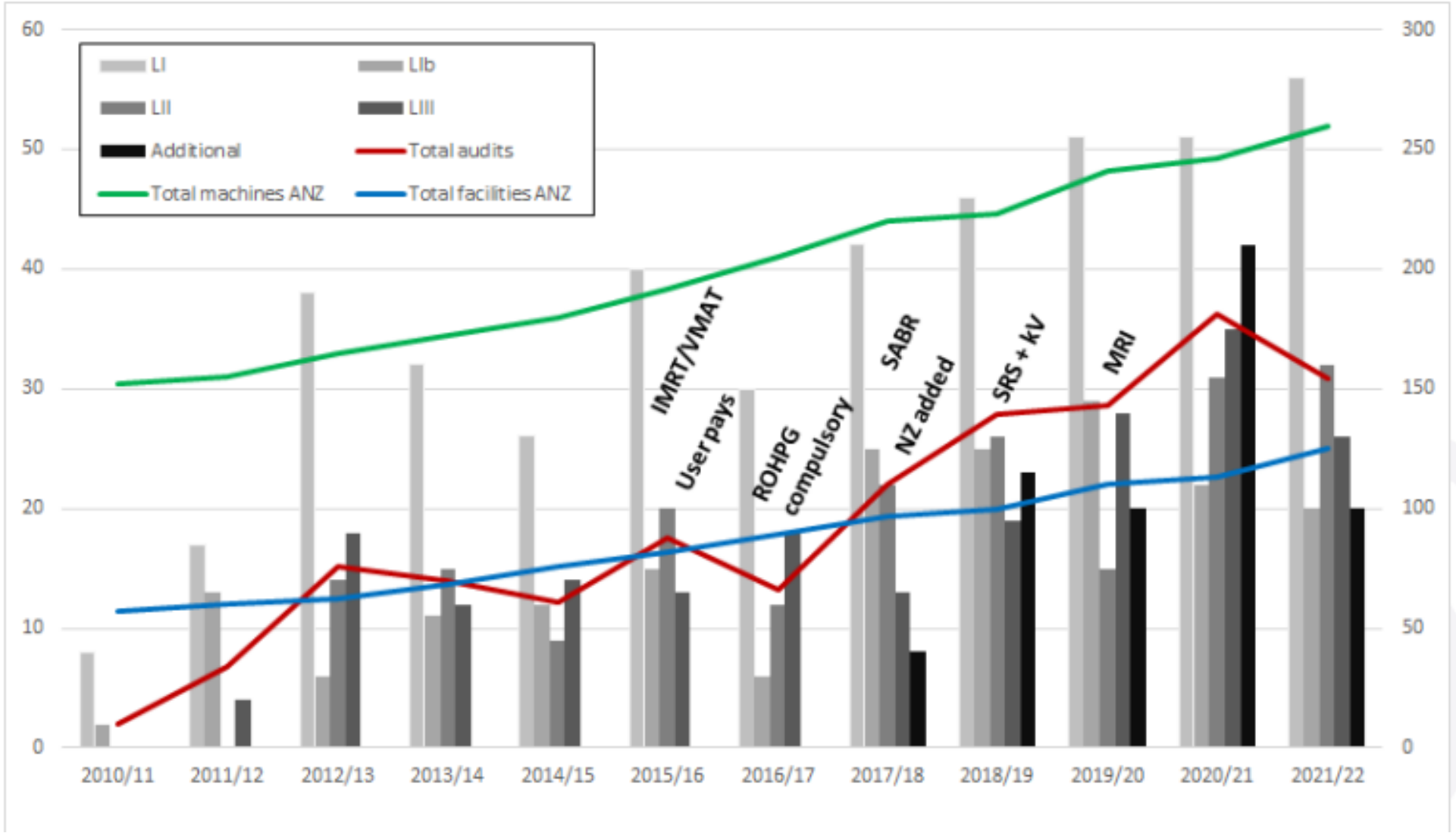




Soft Tissue | Spine | Lung

Courtesy of Andrew

ACDS audit development and delivery



Courtesy of Andrew

5

Malaysian experience

ELSEVIER journal homepage: www.elsevier.com/locate/radphyschem

Dosimetry audits and intercomparisons in radiotherapy: A Malaysian profile

Noramaliza M. Noor[a,*], A. Nisbet[b,c], M. Hussein[c], Sarene Chu S[d], T. Kadni[e], N. Abdullah[e], D.A. Bradley[b,f]

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[b] Department of Physics, University of Surrey, Guildford, Surrey, GU4 8JU, UK
[c] Department of Medical Physics, St Luke's Cancer Centre, The Royal Surrey County Hospital NHS Trust, Edgerton Road, Guildford GU2 7XX, UK
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ARTICLE INFO

Keywords:
Quality audit
Intercomparison
Radiotherapy
Ge-doped
Malaysia

ABSTRACT

Quality audits and intercomparisons are important in ensuring control of processes in any system of endeavour. Present interest is in control of dosimetry in teletherapy, there being a need to assess the extent to which there is consistent radiation dose delivery to the patient. In this study we review significant factors that impact upon radiotherapy dosimetry, focusing upon the example situation of radiotherapy delivery in Malaysia, examining existing literature in support of such efforts. A number of recommendations are made to provide for increased quality assurance and control. In addition to this study, the first level of intercomparison audit i.e. measuring beam output under reference conditions at eight selected Malaysian radiotherapy centres is checked; use being made of 9 μm core diameter Ge-doped silica fibres (Ge-9 μm). The results of Malaysian Secondary Standard Dosimetry Laboratory (SSDL) participation in the IAEA/WHO TLD postal dose audit services during the period between 2011 and 2015 will also been discussed. In conclusion, following review of the development of dosimetry audits and the conduct of one such exercise in Malaysia, it is apparent that regular periodic radiotherapy audits and intercomparison programmes should be strongly supported and implemented world-wide. The programmes to-date demonstrate these to be a good indicator of errors and of consistency between centres. A total of ei + ght beams have been checked in eight Malaysian radiotherapy centres. One out of the eight beams checked produced an unacceptable deviation; this was found to be due to unfamiliarity with the irradiation procedures. Prior to a repeat measurement, the mean ratio of measured to quoted dose was found to be 0.99 with standard deviation of 3%. Subsequent to the repeat measurement, the mean distribution was 1.00, and the standard deviation was 1.3%.

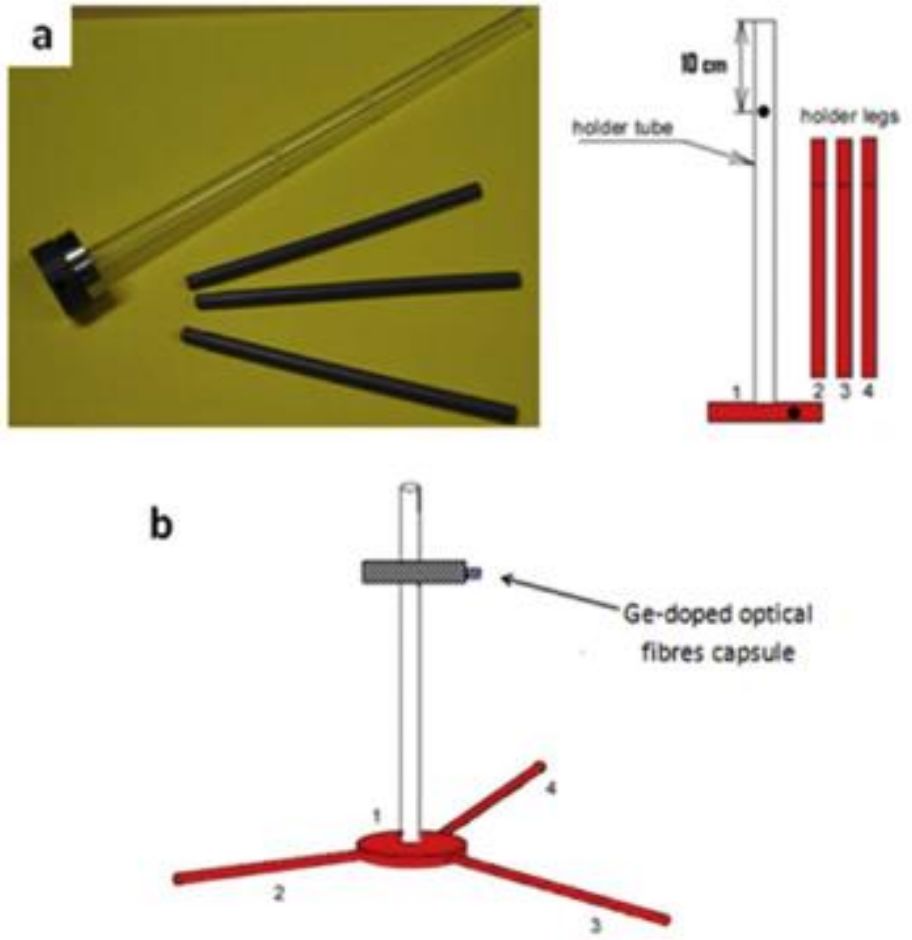


Fig. 2. a) Ge-doped optical fibres holder and constituent support parts; b) Schematic of assemble holder with the Ge-doped fibres capsule for Ge-doped irradiation.

Table 1
Results of TLD measurements for Co-60 and high energy photons in the IAEA/WHO TLD Postal Dose Quality Audit for Malaysian SSDL.

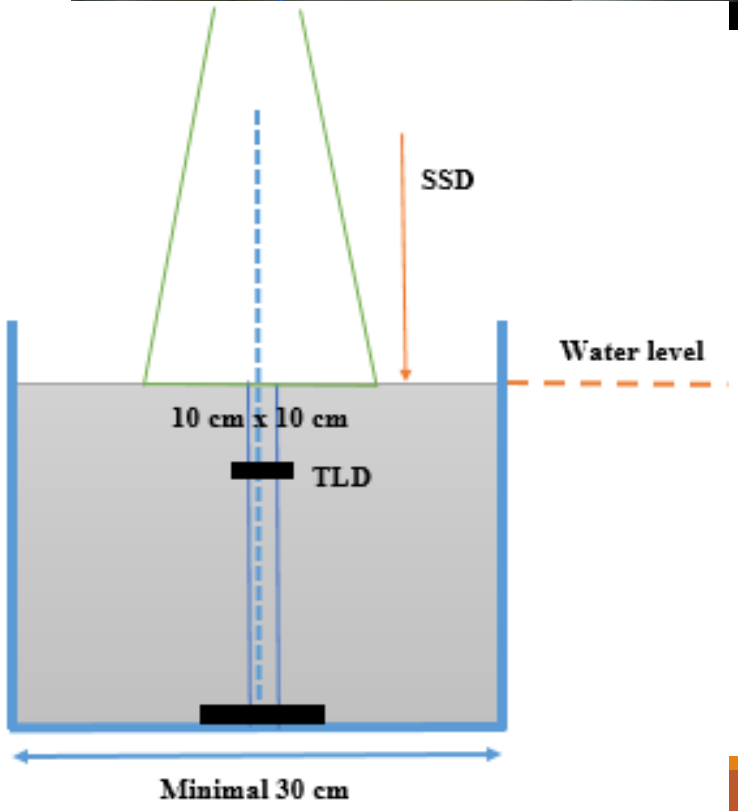
Radiation quality	Year of participation	SSDL stated dose (Gy)	IAEA mean dose (Gy)	Δ (%)[a]	Ratio[b]
1.25 MeV ^{60}Co	2009	2.05	2.05	−0.2	1.00
	2010	2.06	2.12	−2.5	1.03
	2014	2.00	2.01	−0.4	1.00
6 MV X-rays	2011	2.02	2.01	0.6	0.99
	2013	2.01	2.02	−0.4	1.00
	2016	2.00	2.00	0.0	1.00
10 MV X-rays	2012	2.02	2.02	0.0	1.00
	2015	2.03	2.05	−1.2	1.01

[a] Percentage deviation relative to IAEA measured dose = 100x (User stated dose − IAEA mean dose)/IAEA mean dose.
[b] Ratio = IAEA mean dose/User stated dose.

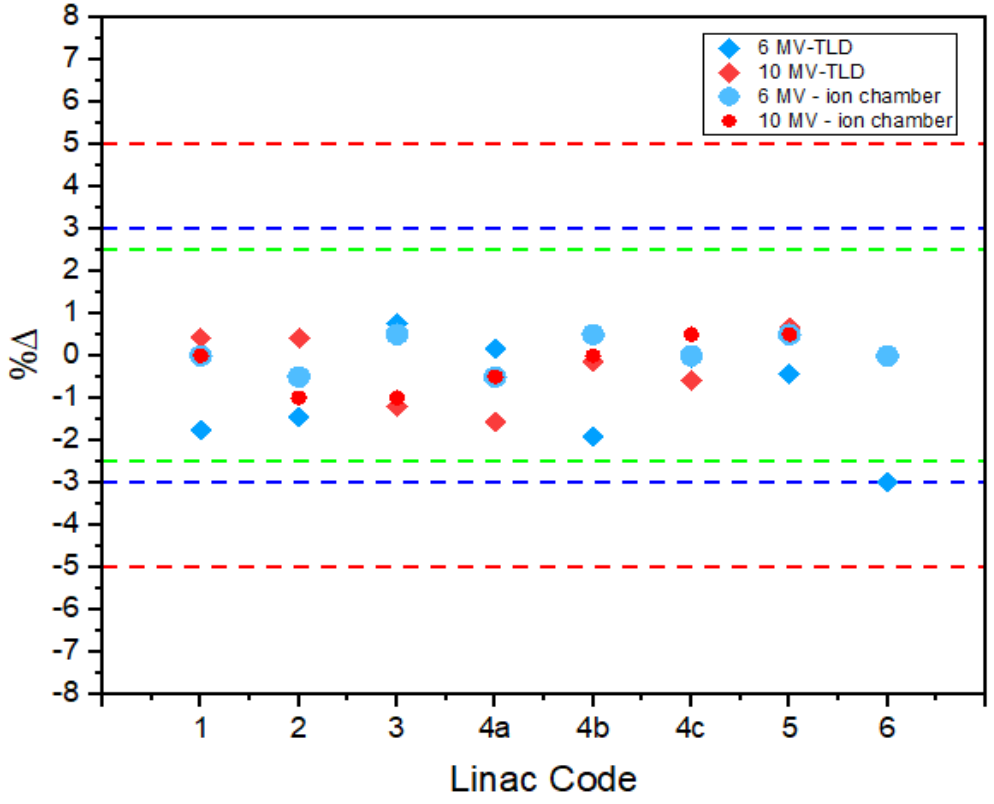
Indonesia

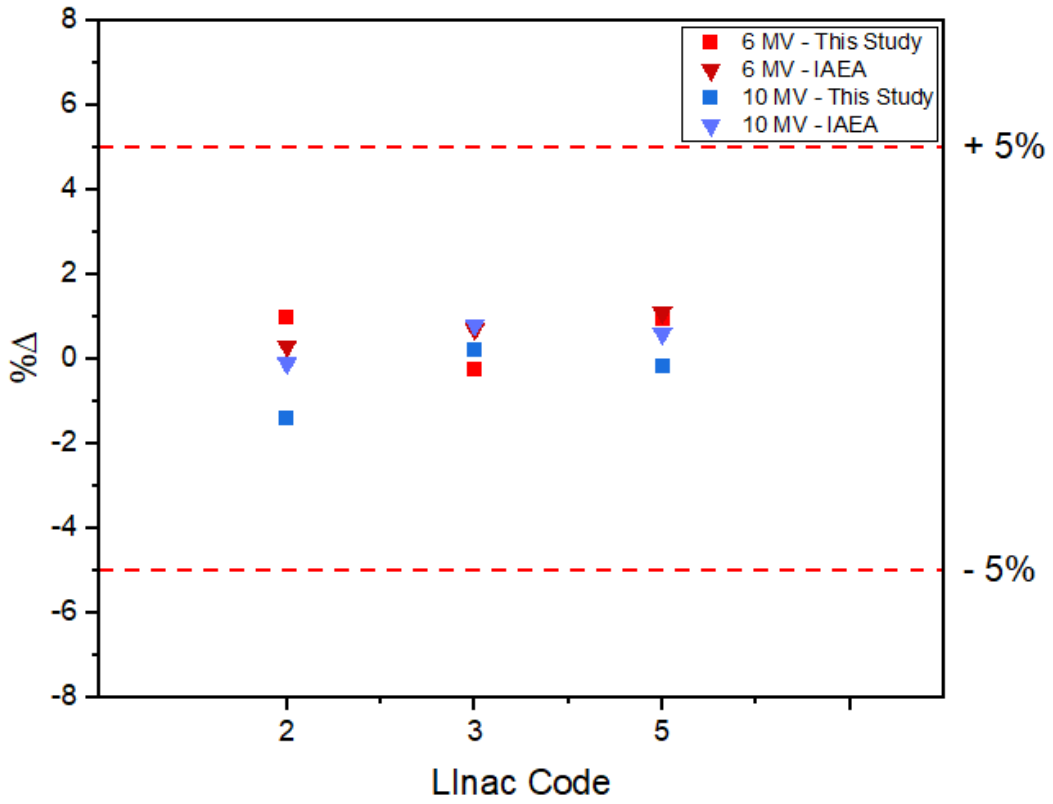
- **Trial – research Study**
  - Output Calibration
  - End-to-end study for IMRT follow TG119 : 2D dose
- **Nuclear Regulatory Agency**
  - Technical document preparation
  - Stakeholders: Indonesian Association of Physicists in Medicine

Audit Output Linac: Point Dose

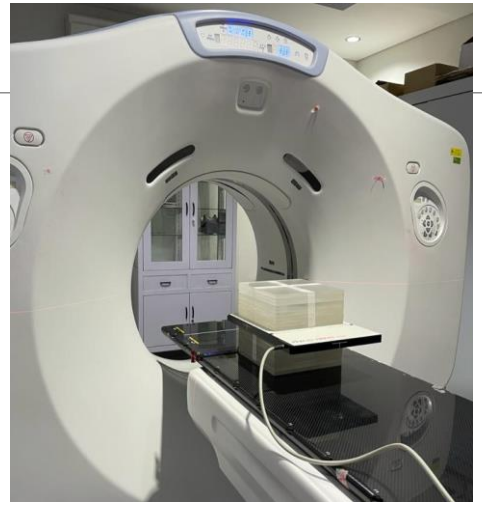


Linac Code	Linac	Ionization Chamber	Energy (MV)
1	Varian Clinac iX	IBA FC 65 G	6 and 10
2	Varian Trilogy	IBA FC 65 G	6 and 10
3	Varian Trilogy	IBA FC 65 G	6 and 10
4a	Elekta Versa HD	IBA FC 65 G	6 and 10
4b	Varian Trilogy	IBA IC 70 Farmer	6 and 10
4c	Varian Trilogy	IBA IC 70 Farmer	6 and 10
5	Elekta Versa HD	PTW 30013 Farmer	6 and 10
6	Varian Unique	PTW 30013 Farmer	6

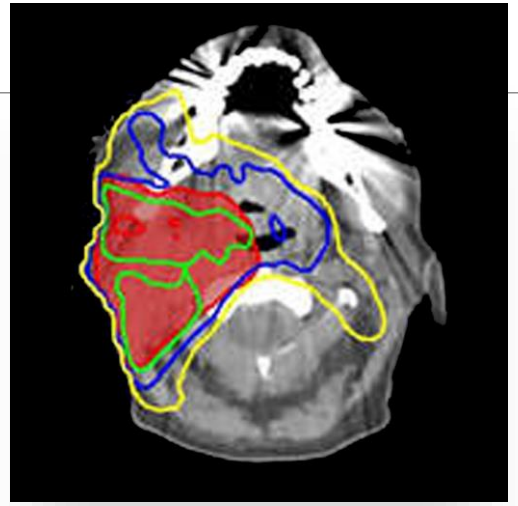

6 MV-TLD
10 MV-TLD
6 MV - ion chamber
10 MV - ion chamber
%Δ
Linac Code
1
2
3
4a
4b
4c
5
6


6 MV - This Study
6 MV - IAEA
10 MV - This Study
10 MV - IAEA
+ 5%
- 5%
%Δ
LInac Code
2
3
5

Audit Output Linac: Planar Dose

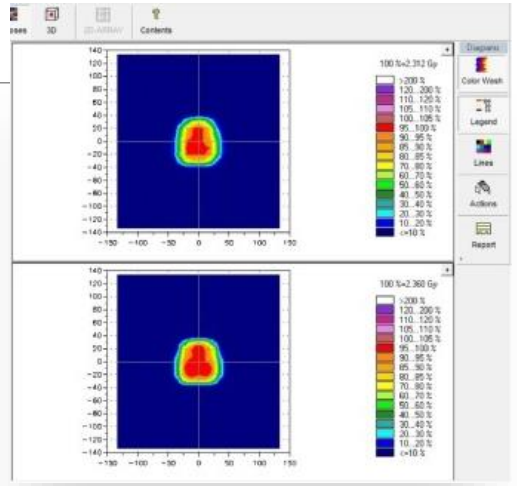


CT Simulator



Treatment Planning System

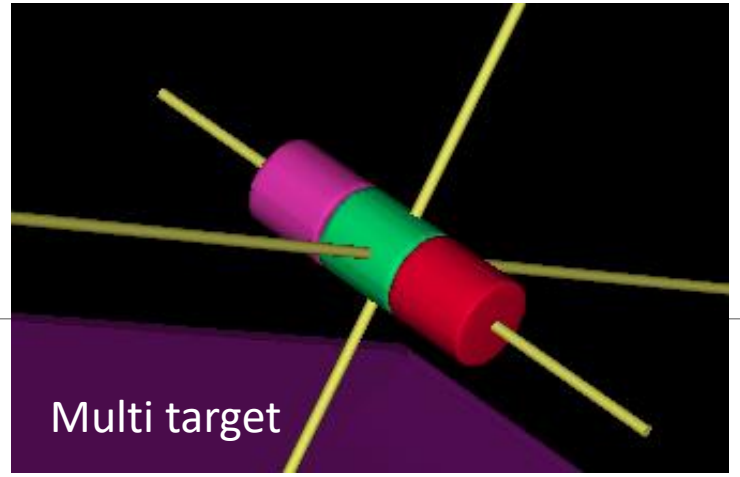
Measurement2D (Planar)



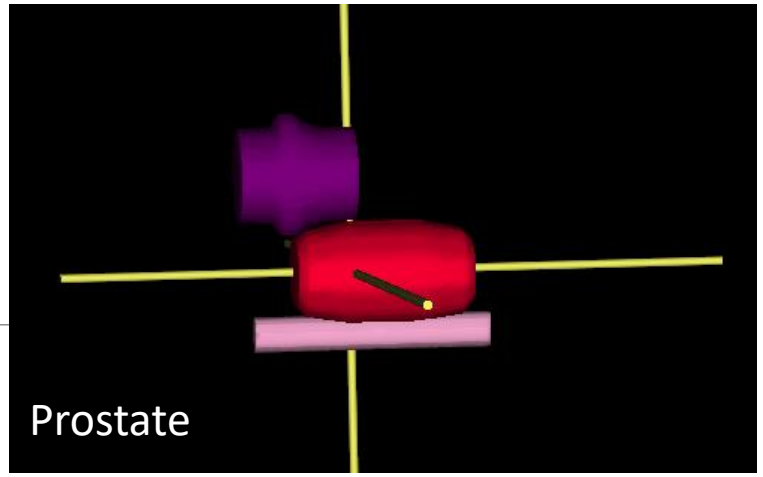
Gamma Index Evaluation

Methods

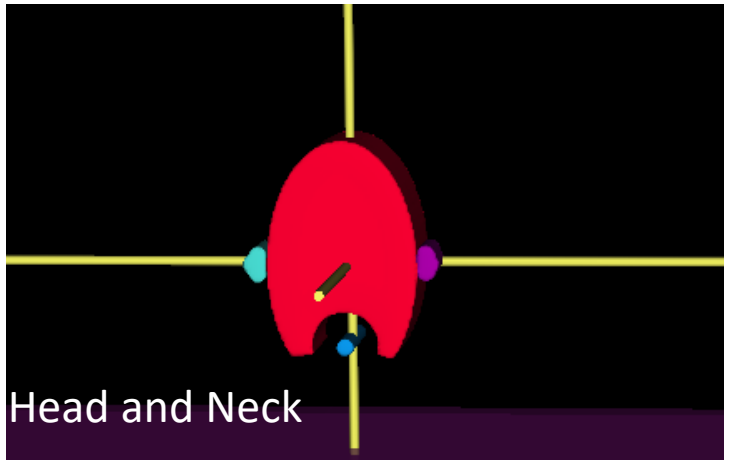
Target Structure



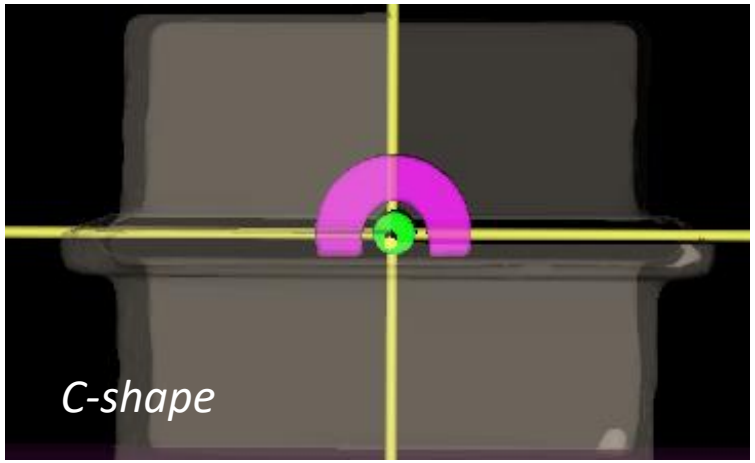
3 target structures: cylindrical with diameter 4 cm and length 4 cm.



PTV ellipses, rectum and Bladder as OAR

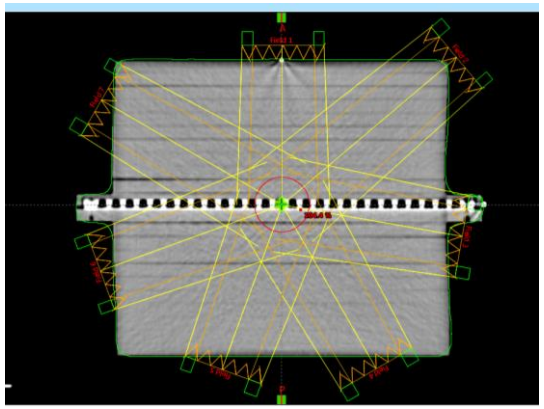


PTV and 2 OAR : parotid left and parotid right and spinal cord



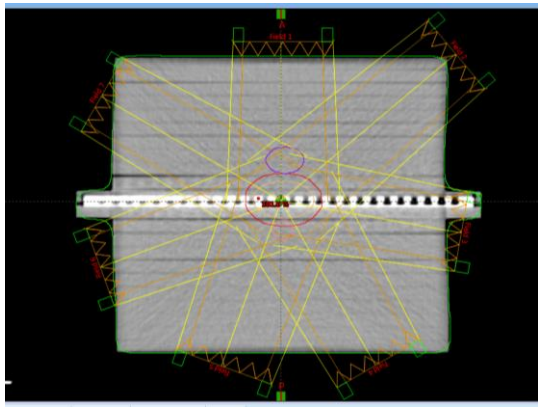
PTV with C -shape

2. Radiotherapy Plan



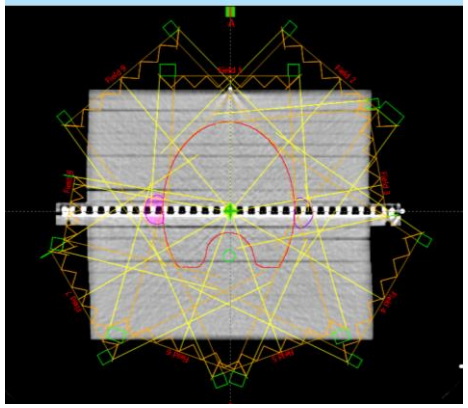
- **Multitarget Test**

7 gantry angle with interval 50˚. Total dose prescription is 50Gy (2 Gy/fraction, 25 fraction).



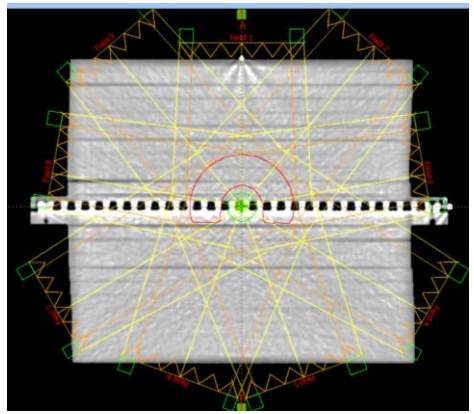
- **Prostate Test**

7gantry angle with interval 50˚. Total dose prescription is 80Gy (2 Gy/fraction, 40 fraction).



- **Head and Neck Test**

9 gantry angle with interval 40˚. Total dose prescription is 50 Gy (2 Gy/fraction, 25 fraction).



- ***C* (*C Shape*) Test**

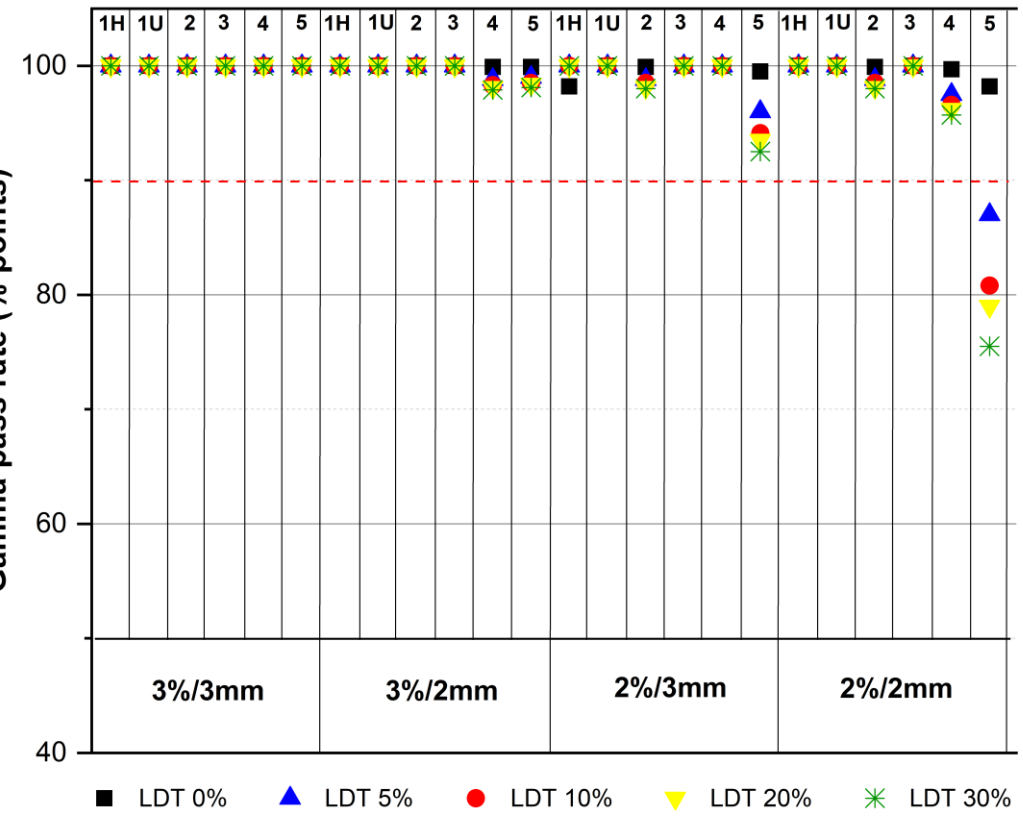
Two Plans :

C-easy shape : D10% < 25 Gy

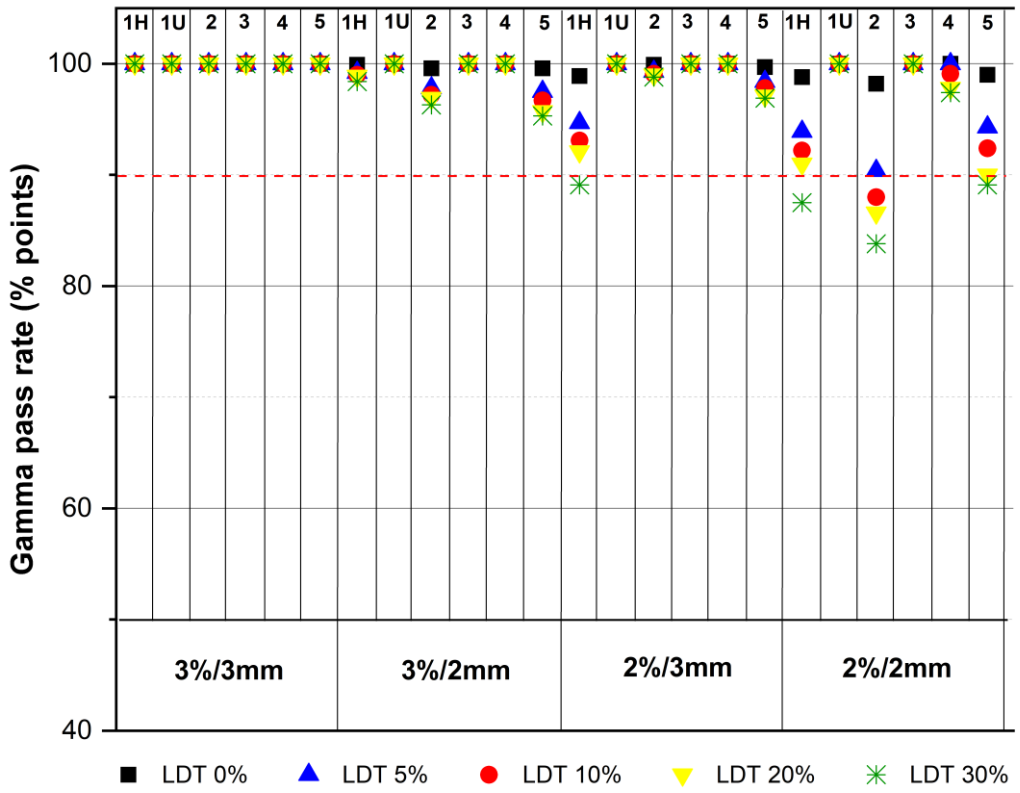
C-difficult shape : D10% < 10 Gy

9 gantry angle with interval 40˚. Total dose prescription 50 Gy (2 Gy/fraction, 25 fraction).

Gamma Index Analysis

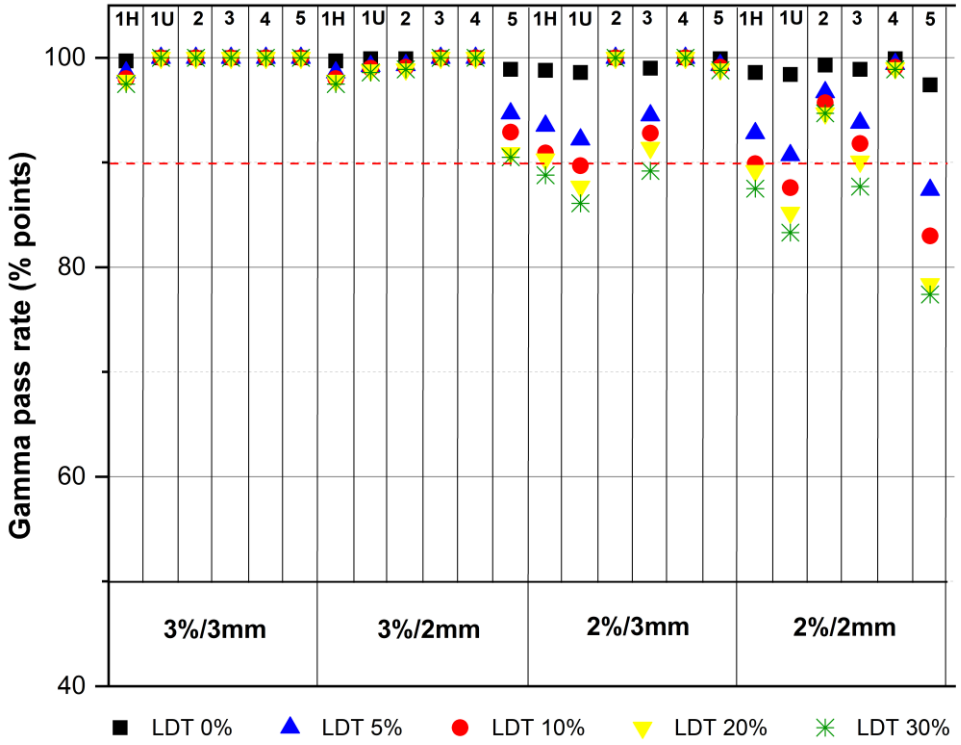


2. Prostate Test



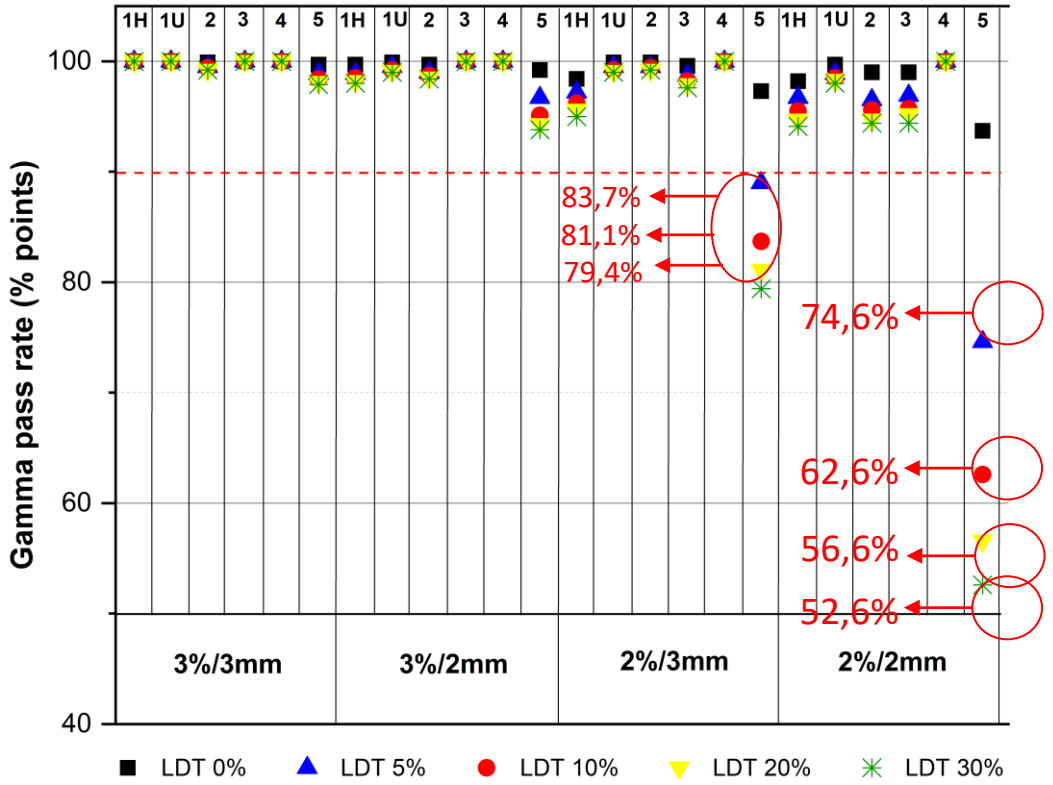
1. Multitarget Test

All centers obtained a passing rate above action level which is defined by AAPM TG-119 dan Crowe at al, 2016



4. C-Easy Shape test

All centers obtained a passing rate above action level which is defined by AAPM TG-119 dan Crowe at al, 2016



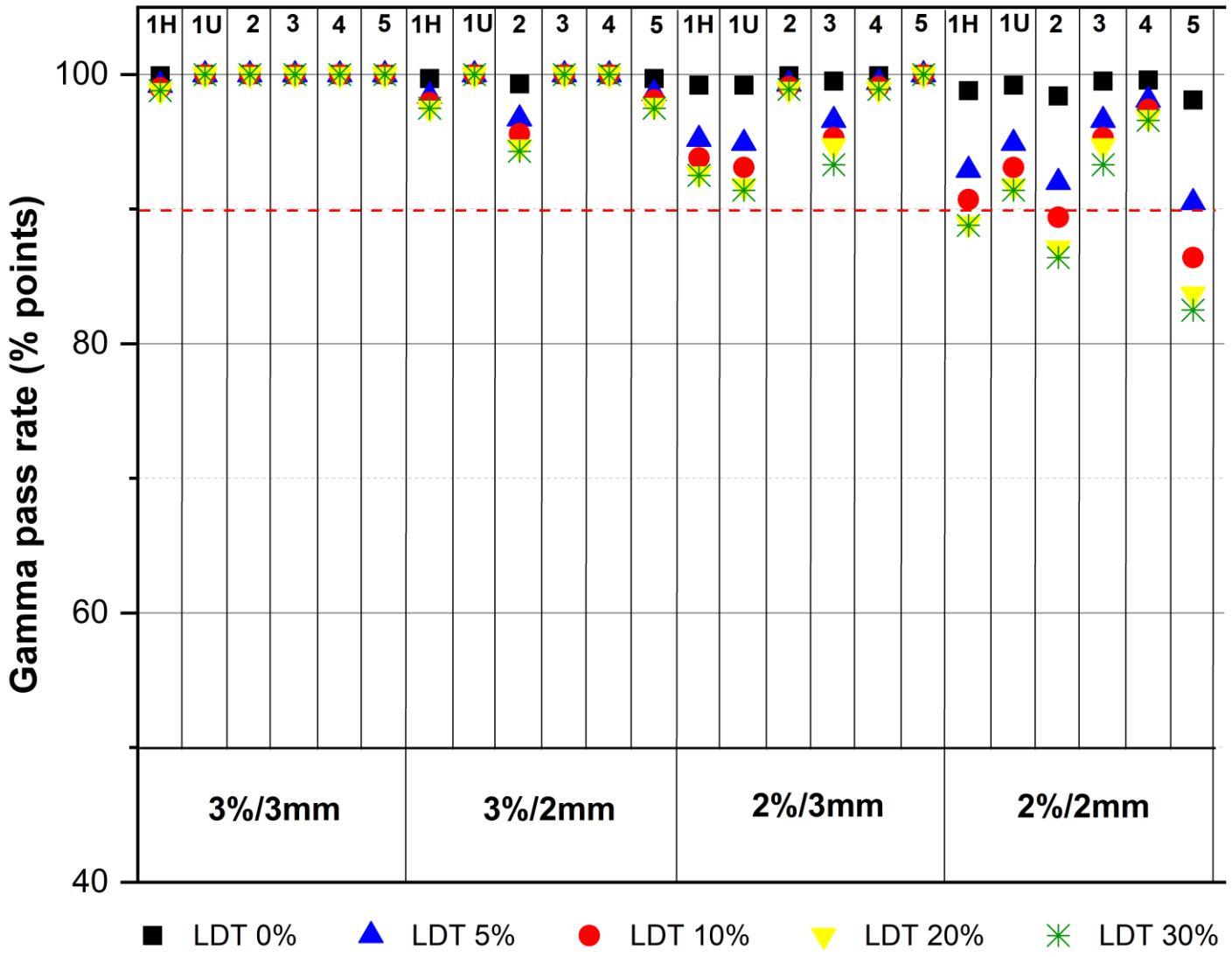
3. Kasus Uji Kepala dan Leher

Center 5 memiliki nilai *passing rate* melewati batas toleransi:

- Pada kriteria 2%/3 mm pada LDT 10%, 20% dan 30%
- Pada kriteria 2%/2 mm pada LDT 5%, 10%, 20% dan 30%.

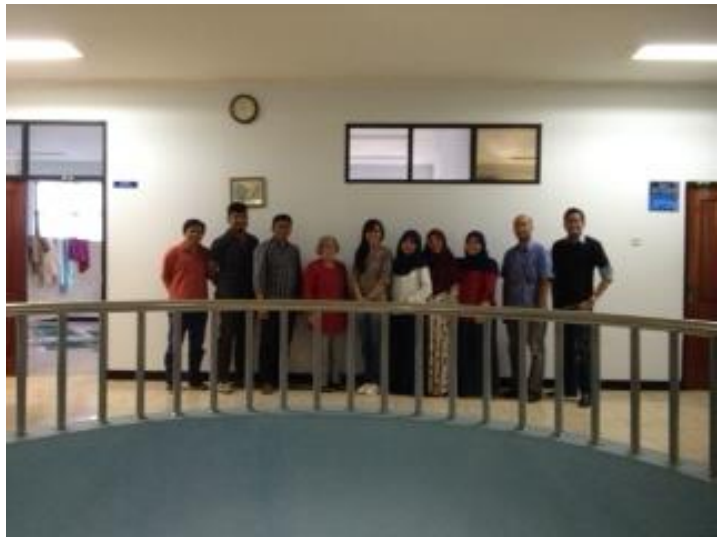
5. C-shape difficult

All centers obtained a passing rate above action level which is defined by AAPM TG-119 dan Crowe at al, 2016



Conclusion

- IAEA and RPC have success story for development of dose audit in radiotherapy
- Some voluntary study have been conducted in regional or national level
- The implementation of national dose audit needs a regulation by national authority
- The improvement of audit dosimetry methods is needed and depend on the radiotherapy development



Thank You ★ Terima Kasih

TUT WURI HANDAYANI

KEMENTERIAN KESEHATAN REPUBLIK INDONESIA

BADAN PENGAWAS TENAGA NUKLIR BAPETEN

batan

ASOSIASI FISIKAWAN MEDIK INDONESIA AFMI