Thai Medical Physicist Society

Move Forward: More **effective** and **efficient** with automatic QA in RT

Sawanee Suntiwong

Radiation Oncology Department, Chulabhorn Hospital, Chulabhorn Royal Academy

Outlines

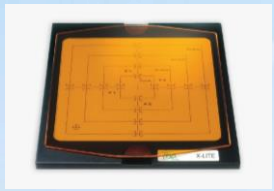
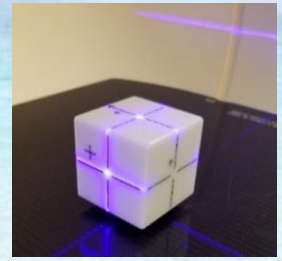
- ❑ Automation in Machine QA
- ❑ Automation in Patient Specific QA

What is Automation?

Automation is the technique, method, or system of operating or controlling a process by highly automatic means reducing human intervention to a minimum.

https://www.make.com

Traditional QA system (Manual)

Mechanical	Dosimetry	IGRT	Test....
			
Device 1	Device 2	Device 3	Device ....
			
Setup 1	Setup 2	Setup 3	Setup ....
Record result test1	Record result test2	Record result test3	Record result test...

Automation QA system

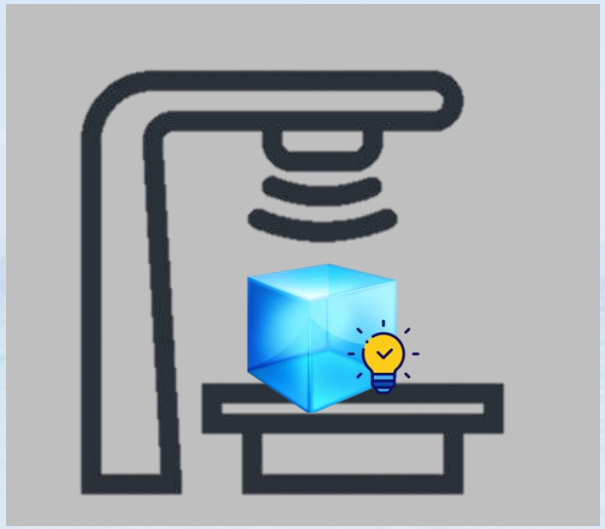
Test1

Test2

Test3

Test...

1 Device
for all test



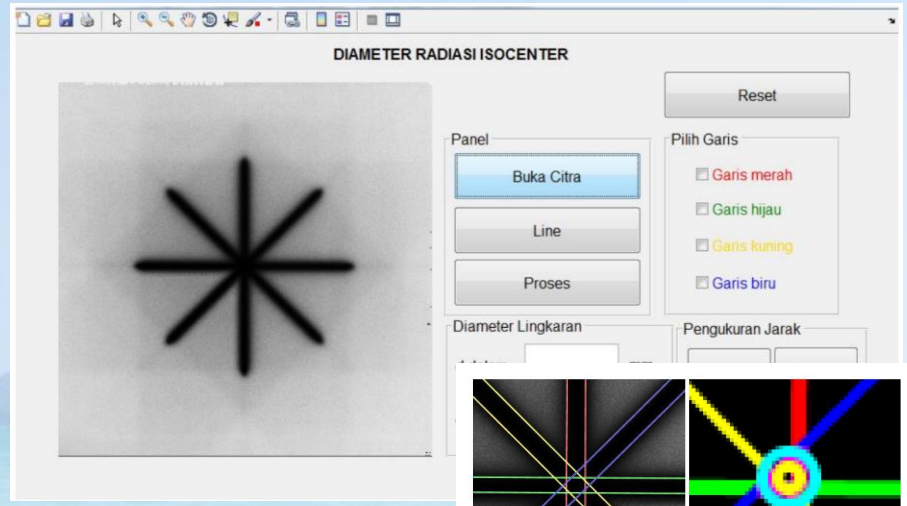
Setup once for all tests

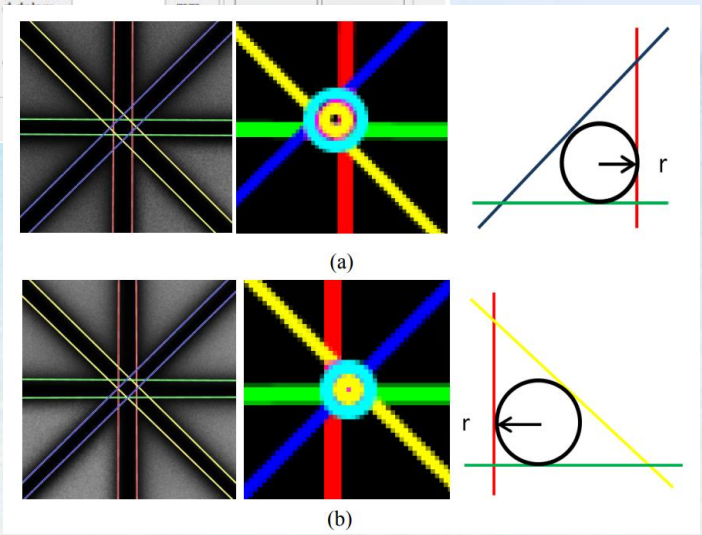
Automated recording and analysis

Automation QA system

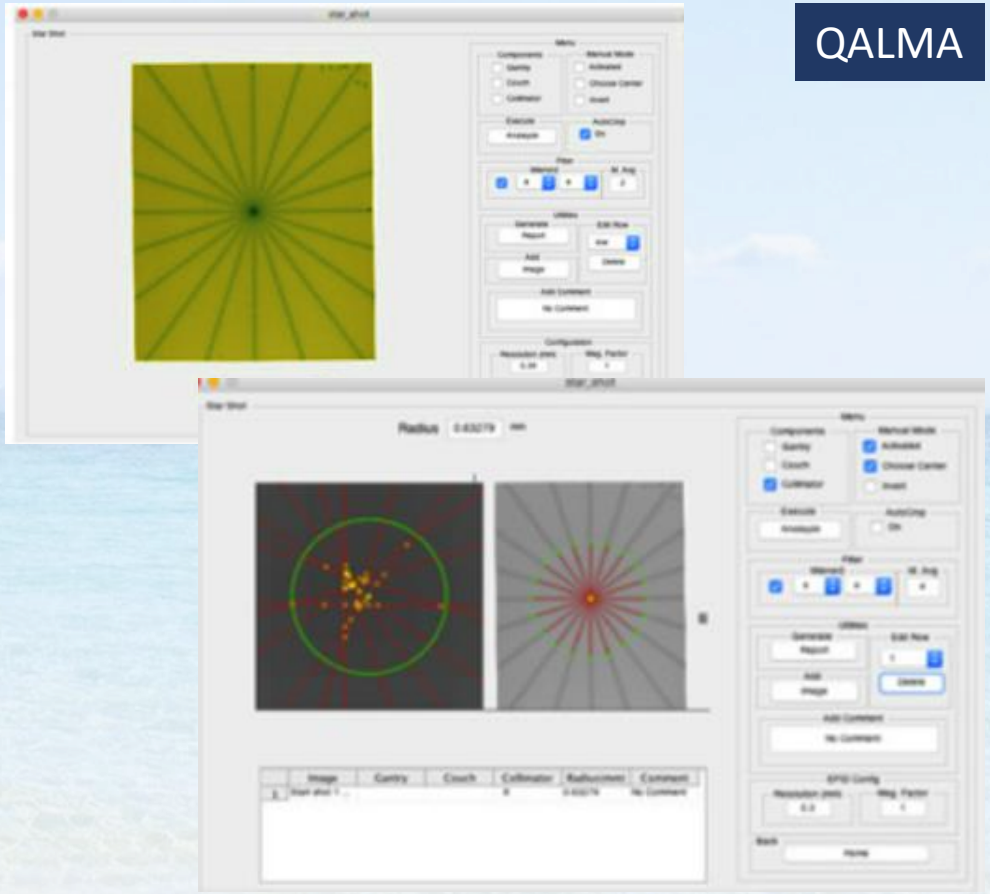
- Hardware
  - Phantom
- Automatic Software And Operation
  - Data analysis
  - Automatic image acquisition
  - Automatic machine operation
  - Image process

Simple Automated Software: MATLAB





QALMA



Muhammad Irsal et al. : Journal of Physics: Conf. Series 855 (2017)

M.M. Rahman et al. / SoftwareX 7 (2018) 101–106

Advance Automated Software: Commercial

Use of an automated software module for monthly routine Machine QA tests

E. Bonanno,[a] G.R. Borzì,[a] N. Cavalli,[a] M. Pace,[a] G. Stella,[b,*] L. Zirone[a] and C. Marino[a]

[a]Medical Physics Department, Humanitas Istituto Clinico Catanese, SP 54 n. 11, Contrada Cubba Marletta, 11, 95045 Misterbianco, Italy
[b]DPhysics and Astronomy Department E. Majorana, University of Catania, Via S. Sofia, 64, 95123 Catania, Italy

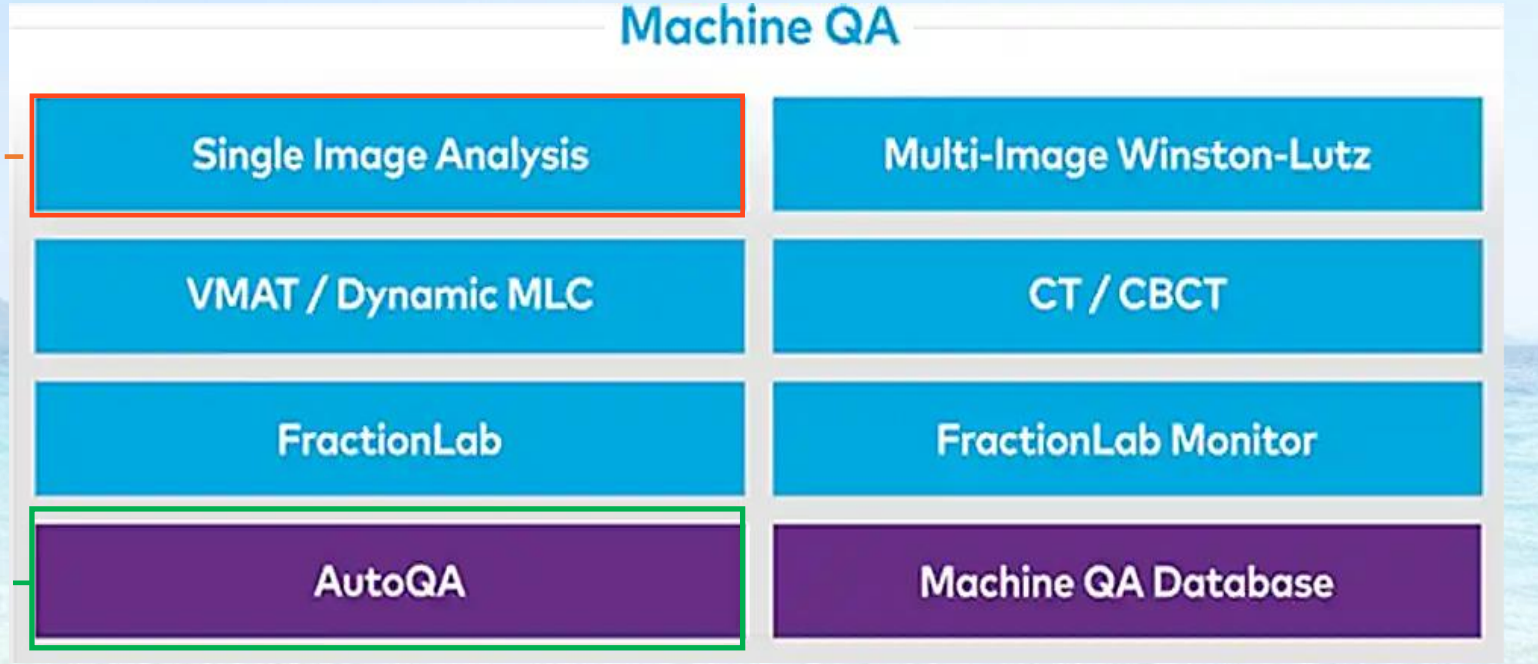
2023 JINST 18 T07010

Software automation

DoseLab

Simple Software Automation

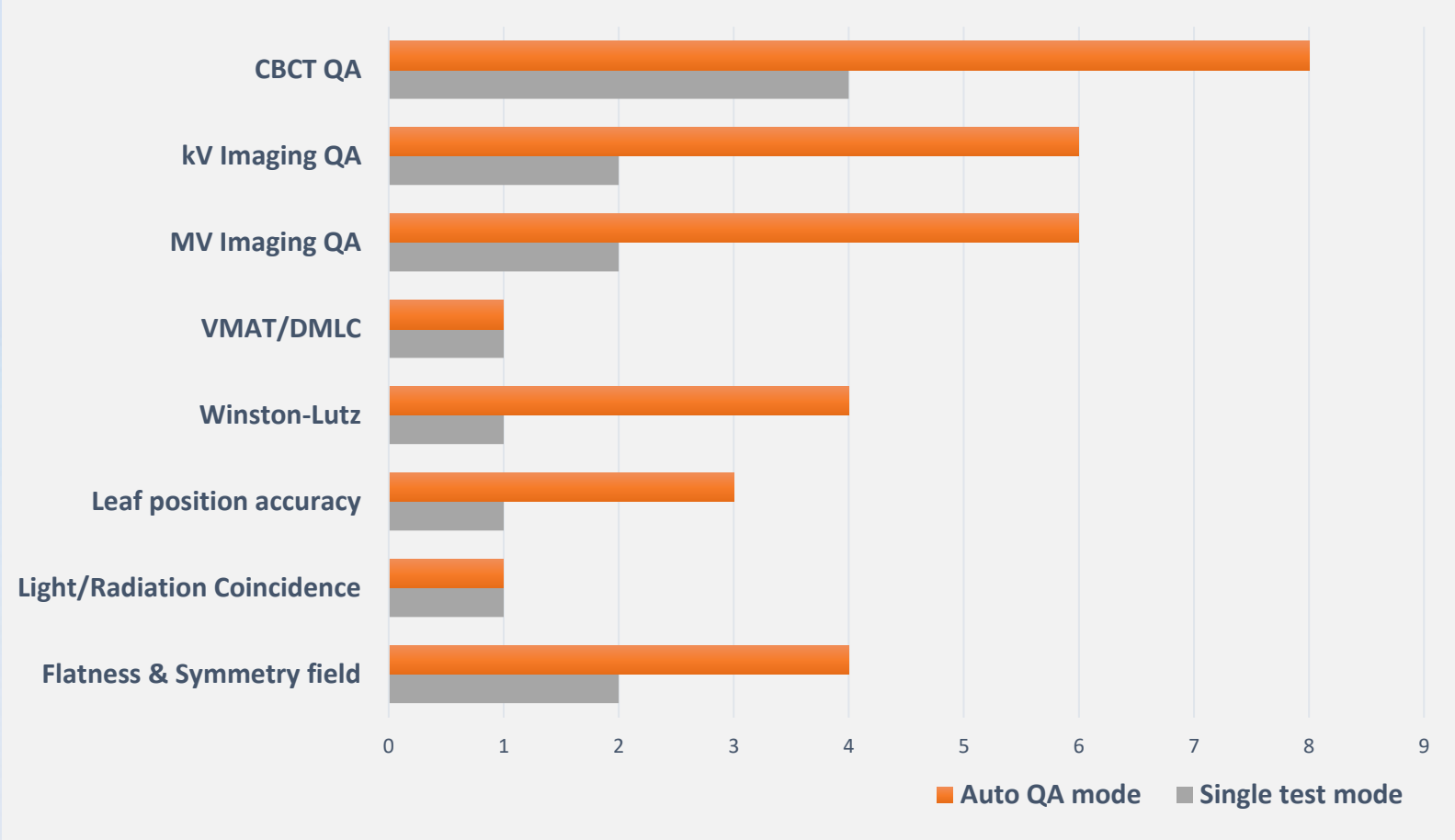
Advance Software Automation



Bonanno et al.

Software automation

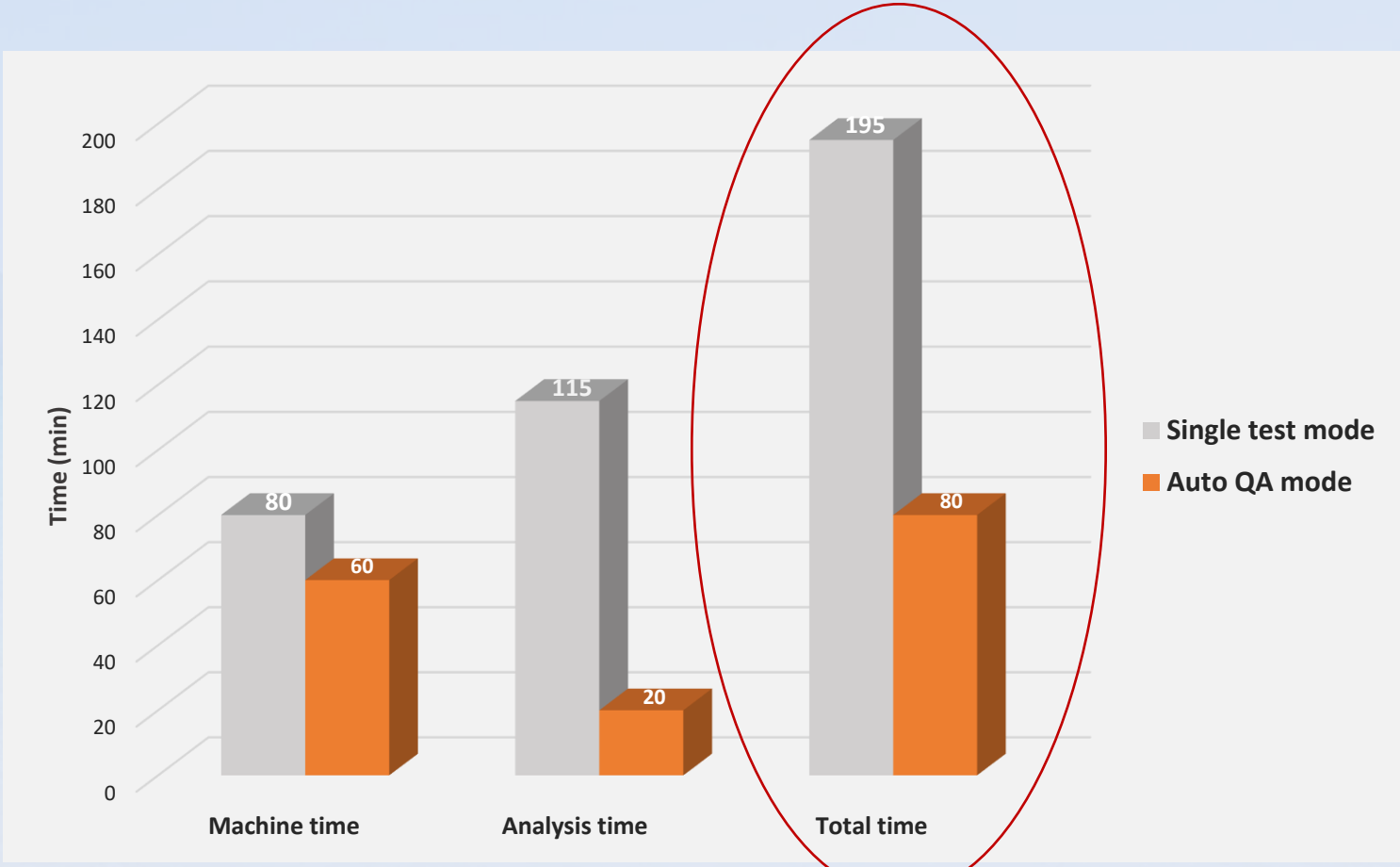
Number of collected data between Single test mode and Auto QA mode



Bonanno et al.

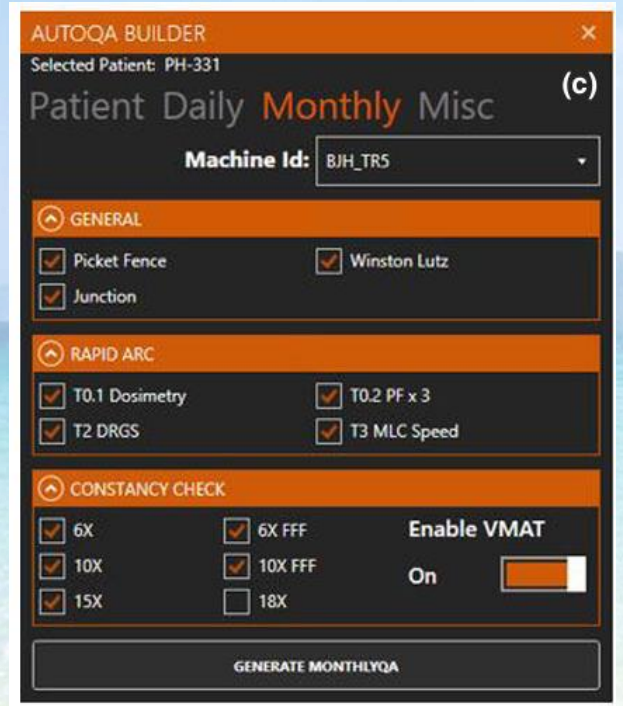
Software automation

Comparative of time consuming between single test mode and Auto QA mode



Bonanno et al.

Software automation



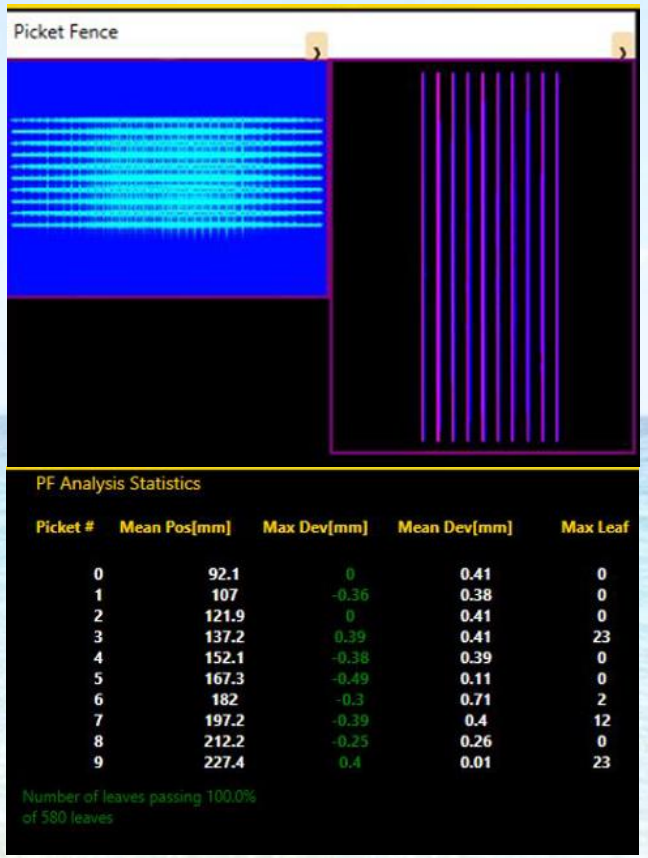
AutoQA Builder

Create QA plans in TPS:

- Daily QA
- Monthly QA
- Quarterly QA
- Other periodic QA plans

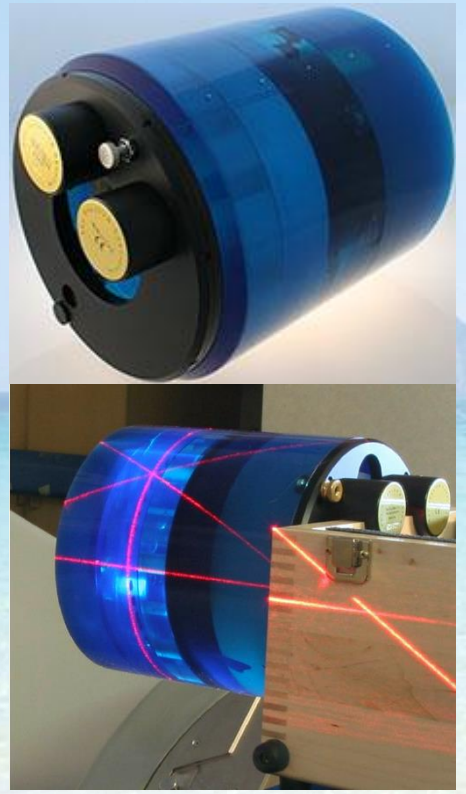
AutoQA Analysis

To analyze images collected on the EPID



Schmidt et al. J Appl Clin Med Phys 2021; 22:6:26–34

Phantom and automatic analysis software

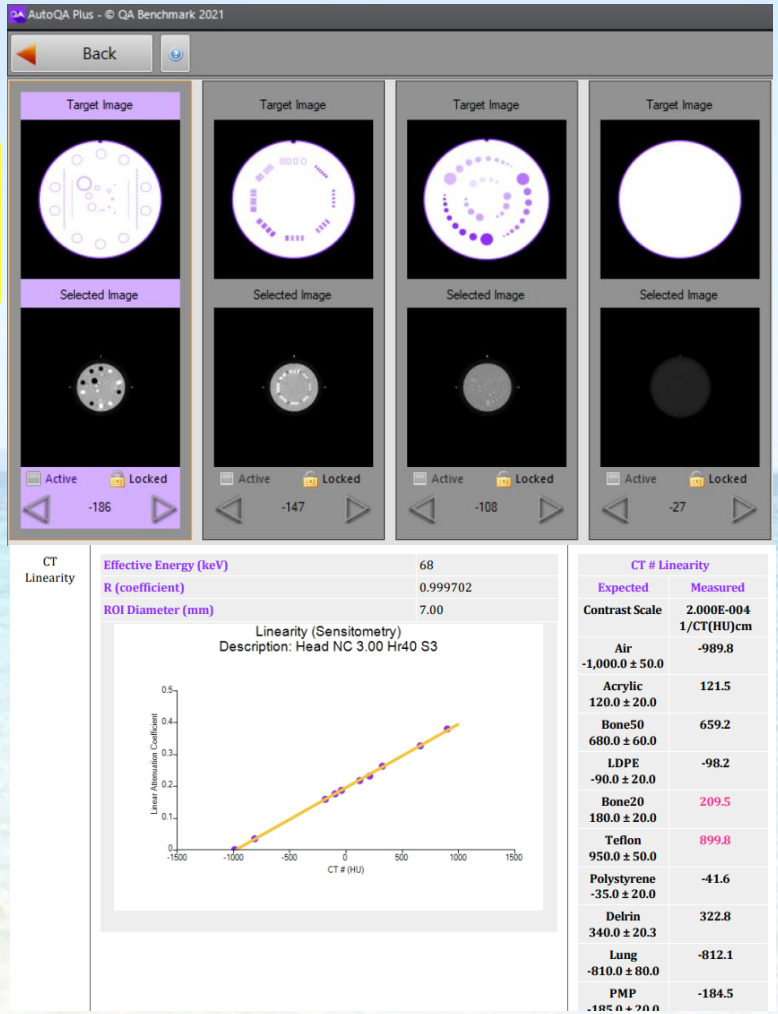


Catphan® 700

Automatic analysis software

- CT Linearity
- Slice thickness
- Modulation transfer function
- Low contrast
- Contrast Noise ratio
- Uniformity index

AutoQAPlus

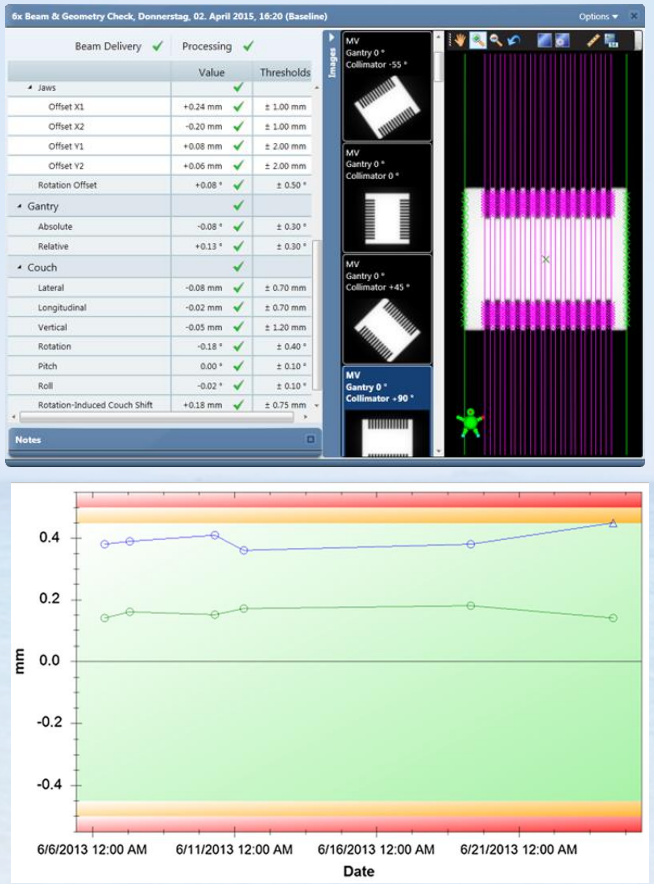


Dedicated phantom and Automatic analysis software

IsoCal Phantom

Machine Performance Check (MPC) Setup

MPC Operation



MPC Evaluation

Auto QA in Radiotherapy: Hardware and software

Beam Check Tests		Geometry Tests	
Beam output constancy	TG-142:Daily QA	Radiation Isocenter Size	
Beam uniformity		Coincidence with MV isocenter	TG-142:Daily QA
Beam center shift		Coincidence with kV isocenter	TG-142:Daily QA
		Collimator readout accuracy	
		Gantry readout accuracy	
		MLC leaf position and reproducibility	
		Jaw position accuracy	TG-142:Daily QA
		Couch position accuracy up to 6D	

How reliable is the MPC?

RADIATION ONCOLOGY PHYSICS

Independent validation of machine performance check for the Halcyon and TrueBeam linacs for daily quality assurance

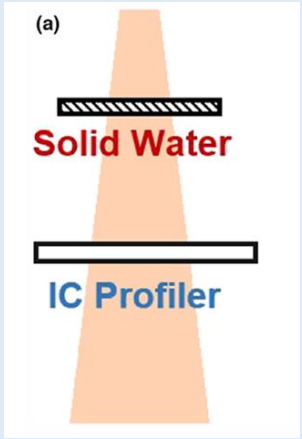
Yuting Li[1,2] | Tucker Netherton[1,3] | Paige L. Nitsch[3] | Song Gao[3] | Ann H. Klopp[3] | Peter A. Balter[3] | Laurence E. Court[3]

[1]The University of Texas Graduate School of Biomedical Sciences at Houston, Houston, USA
[2]Department of Radiation Oncology, The Ohio State University Wexner Medical Center, Columbus, OH, USA
[3]Department of Radiation Physics, Division of Radiation Oncology, The University of Texas MD Anderson Cancer Center, Houston, TX, USA

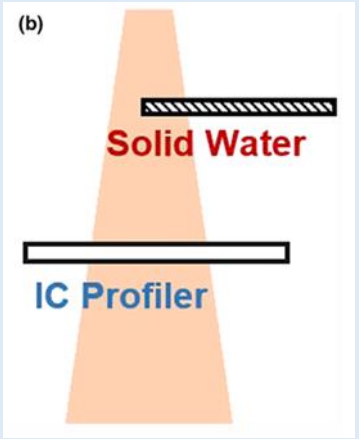
J Appl Clin Med Phys 2018; 19:5:375–382

MPC Error detection: Beam Check Tests

Beam Check Tests	Error detection test	Standard Device
	Halcyon	
Beam output constancy	Add solid water slabs	IC Profiler
Beam uniformity	Add the half of solid water slabs	IC Profiler



Measurement set up for beam output constancy

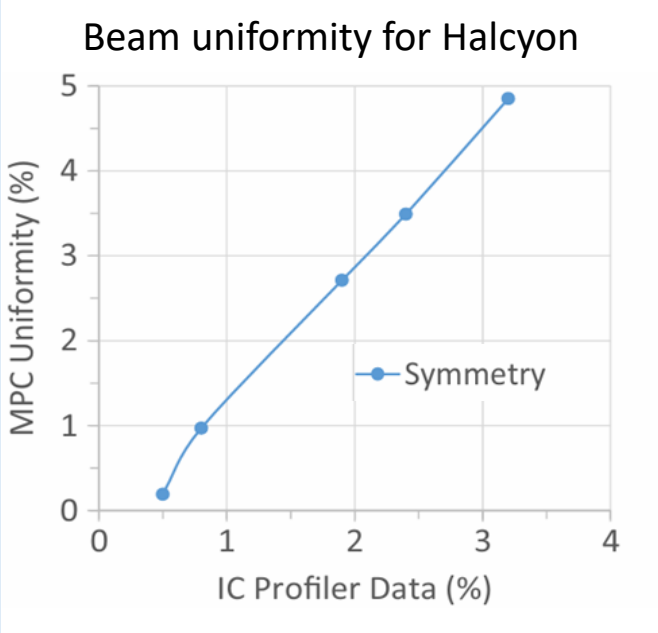


Measurement set up for beam uniformity

Yuting Li et al.

Results: Beam Check test

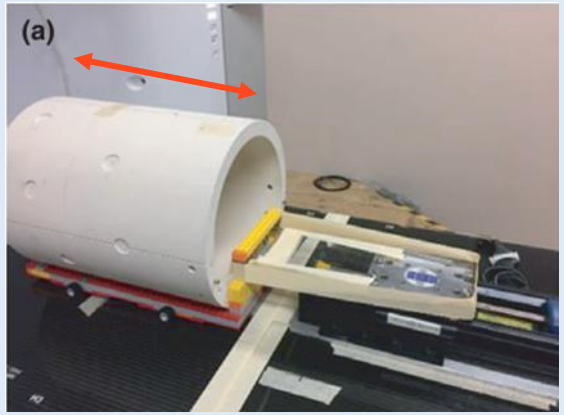
Beam check tests	MPC reading – IC profiler
	Halcyon
Beam output constancy (%)	1.31 ± 0.48



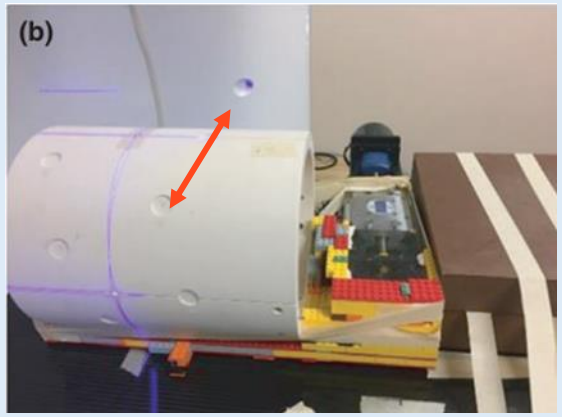
Yuting Li et al.

MPC Error detection test: Geometry Tests

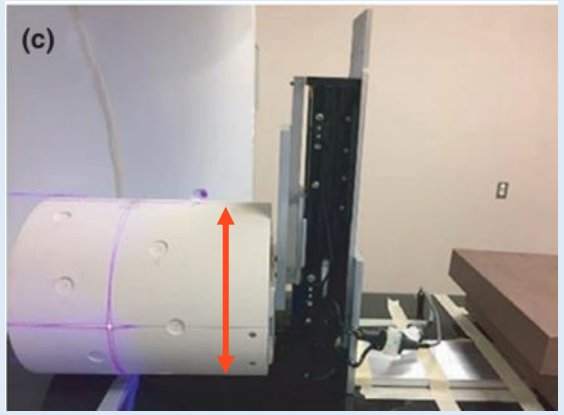
MPC Phantom shift during MPC test



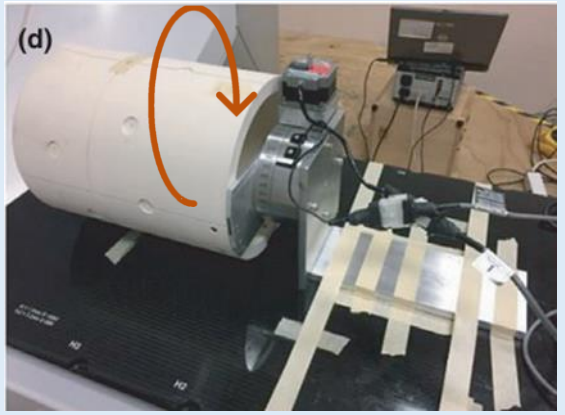
Couch Longitudinal



Couch Lateral



Couch Vertical



Relative Gantry rotation

Yuting Li et al.

Results: Geometry test

Geometry tests	MPC reading - known value
	Halcyon
Couch Translation	
Longitudinal	0.02 ± 0.03 mm
Lateral	0.09 ± 0.06 mm
Vertical	0.02 ± 0.02 mm

Yuting Li et al.

Results of MPC relative gantry rotation tests

Machine	Angle offset (degree)	MPC results (degree)
Halcyon	0.1	0.04 (0.02 – 0.05)
	0.3	0.16 (0.13 – 0.16)
	0.5	0.30 (0.23 – 0.37)
	1.0	0.64 (0.47 – 0.82)
	1.5	0.96 (0.71 – 1.21)
	2.0	1.30 (0.96 – 1.64)
	5.0	3.38 (2.47 – 4.29)

Yuting Li et al.

The MPC is capable of detecting errors in beam constancy and mechanical parameters to a level that is sufficiently accurate to be effectively used for daily QA

Yuting Li et al.

ราชวิทยาลัยจุฬาภรณ์
CHULABHORN ROYAL ACADEMY

Thai Medical Physicist Society

RADIATION ONCOLOGY PHYSICS

Evaluation of the truebeam machine performance check (MPC): mechanical and collimation checks

Michael P Barnes[1,2,3] | Peter B Greer[1,3]

[1]Department of Radiation Oncology, Calvary Mater Hospital Newcastle, Waratah, NSW, Australia
[2]School of Medical Radiation Sciences, University of Newcastle, Newcastle, NSW, Australia
[3]School of Mathematical and Physical Sciences, University of Newcastle, Newcastle, NSW, Australia

J Appl Clin Med Phys 2017; 18:3:56–66

Daily Quality Assurance Efficiency Evaluation Using SunCHECK Machine and Machine Performance Check

Cassandra Stambaugh [1], Jessica Yancey [1], Utkarsh Shukla [1], Christopher Melhus [1], Nathaniel Stambaugh [2]

1. Radiation Oncology, Tufts Medical Center, Boston, USA 2. Mathematics, Dexter Southfield School, Brookline, USA

2023 Stambaugh et al. Cureus 15(3)

Evaluation of the truebeam machine performance check (MPC): OBI X-ray tube alignment procedure

Michael P. Barnes[1,2,3] | Dennis Pomare[1] | Frederick W. Menk[3] | Buiron Moraro[4] | Peter B. Greer[1,3]

J Appl Clin Med Phys 2018; 19

Evaluation of the truebeam machine performance check (MPC) geometric checks for daily IGRT geometric accuracy quality assurance

Michael P Barnes[1,2,3] | Peter B Greer[1,3]

J Appl Clin Med Phys 2017; 18:3:200–206

การประกันคุณภาพเครื่องฉายรังสี รุ่น TrueBEAM ด้วยวิธี Machine Performance Check (MPC)

พันทิวา อุณห์ศิริ
สาขารังสีรักษาและมะเร็งวิทยา
ฝ่ายรังสีวิทยา โรงพยาบาลจุฬาลงกรณ์ สภากาชาดไทย

Journal of Thai Association of Radiation Oncology Vol. 24 No. 1 January - June 2018

A multi-institutional evaluation of machine performance check system on treatment beam output and symmetry using statistical process control

Diana Binny[1,2] | Trent Aland[1,2] | Ben R. Archibald-Heeren[3] | Jamie V. Trapp[2] | Tanya Kairn[2,4] | Scott B. Crowe[2,4]

J Appl Clin Med Phys 2019; 20:3:71–80

MPC is sufficiently accurate to be effectively used for daily QA

RADIATION ONCOLOGY PHYSICS

WILEY

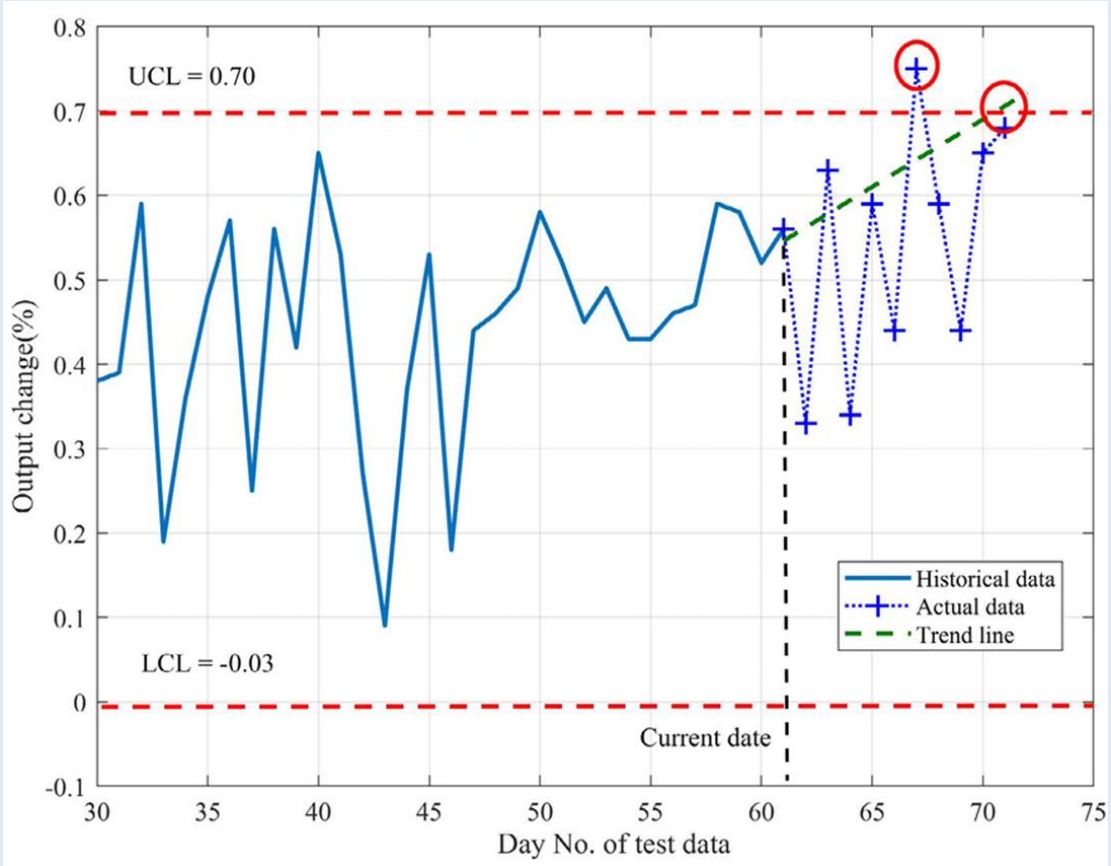
Predictive quality assurance of a linear accelerator based on the machine performance check application using statistical process control and ARIMA forecast modeling

Wayo Puyati[1,2] | Amnach Khawne[1] | Michael Barnes[3,4] | Benjamin Zwan[4,5] | Peter Greer[3,4] | Todsaporn Fuangrod[6]

[1]Department of Computer Engineering, Faculty of Engineering, King Mongkut's Institute of Technology Ladkrabang, Bangkok, 10520, Thailand
[2]Department of Mathematics Statistics and Computer, Faculty of Science, Ubon Ratchathani University, Ubon Ratchathani, 34190, Thailand
[3]Department of Radiation Oncology, Calvary Mater Hospital Newcastle, NSW, 2298,Australia
[4]School of Mathematical and Physical Sciences, University of Newcastle, Newcastle, NSW, 2308, Australia
[5]Central Coast Cancer Centre, Gosford Hospital, Gosford, NSW, 2250, Australia
[6]Faculty of Medicine and Public Health, HRH Princess Chulabhorn College of Medical Science, Chulabhorn Royal Academy, Bangkok, 10210, Thailand

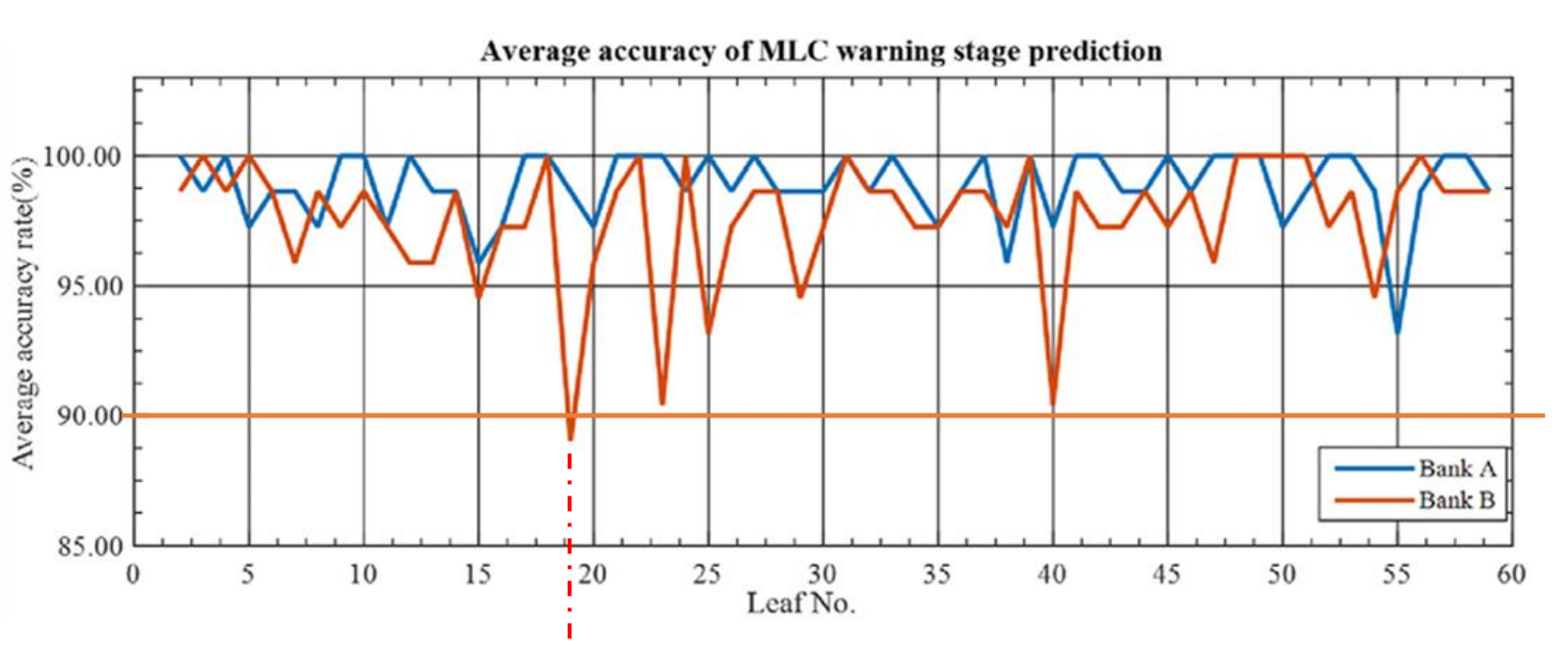
J Appl Clin Med Phys 2020; 21:8:73–82

Example of trend line to detect the output change exceeded the upper control limit



Wayo Puyati et al.

The warning stage prediction using the average accuracy for individual leaf of MLC



Bank B:19th

Predictive quality assurance with MPC:

- Preventative maintenance, which could lead to improved Linac performance
- Reduction in unscheduled Linac downtime

Wayo Puyati et al.

ราชวิทยาลัยจุฬาภรณ์
CHULABHORN ROYAL ACADEMY

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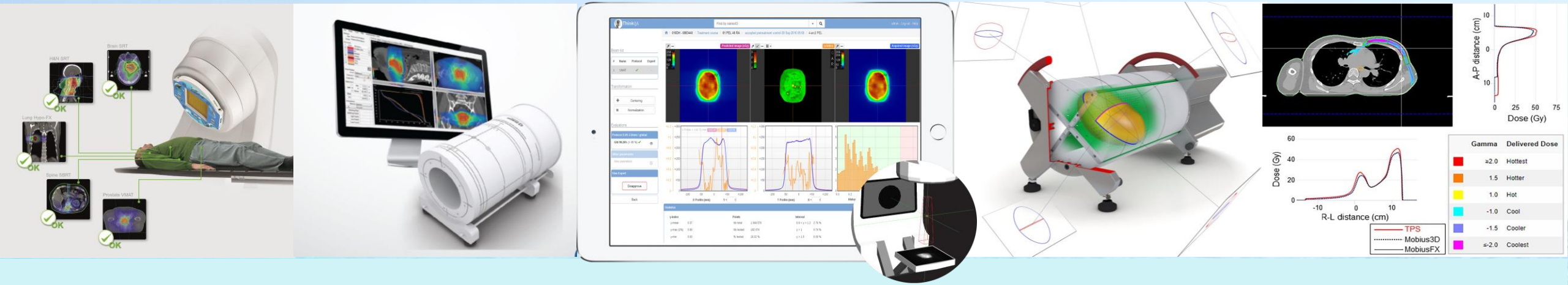
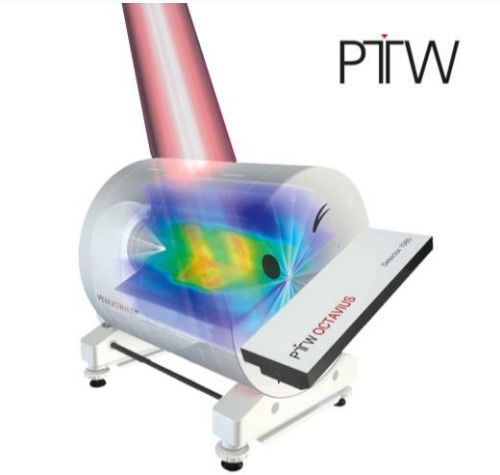


Patient-Specific QA Automation

Patient-Specific QA Automation



Measurement-based

- Phantom
- Detector

Software-based

- Commercial software
- Log file
- AI

Automation levels of measurement-based PSQA

Level 0

No automation

- No computer aided operations

➢ Point dose measurement

Manual setup
Manual calculation

Level 1

Driver assistance

- Human operations with computer

➢ Computer aided measurements using PSQA devices with significant human involvements.

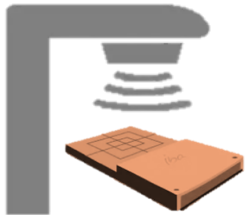
Manual setup device + PSQA Program

Level 2

Partial driving automation

- Automated operations of the TPS computers that allow open access to Operating system

- Manual setup device
- Semi-auto Program in TPS



Manual operating LINAC Control console

Jingqiao Zhang et al. Int. J. Medical Physics, Clinical Engineering and Radiation Oncology

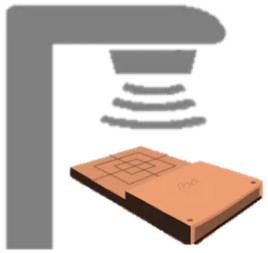
Automation levels of measurement-based PSQA

Level 3

Conditional automation

- Automated operations of vendor computers that don't allow open access to Operating system.

- Manual setup device
- Semi-auto Program in TPS/PSQA software



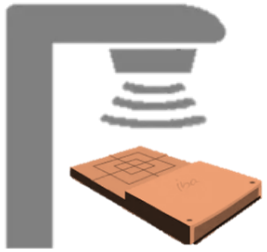
Semi-Auto operating LINAC Control console

Level 4

High automation

- Automated operations of all devices except in-room detector/phantom setups

- Manual setup device
- Automation Program in TPS/PSQA software



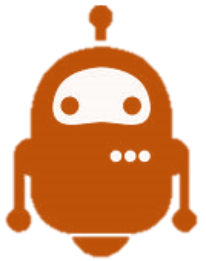
Control console automation

Level 5

Fully automated

- Fully automated PSQA

- In room setup automation
- Automation Program



Control console automation

Jingqiao Zhang et al. Int. J. Medical Physics, Clinical Engineering and Radiation Oncology

Software-based

If machine QAs are performed on the delivery system at a high enough performance and frequency

Move forward

Software-base for PSQA

Siochi RAC. Med Phys.2013;40(7)

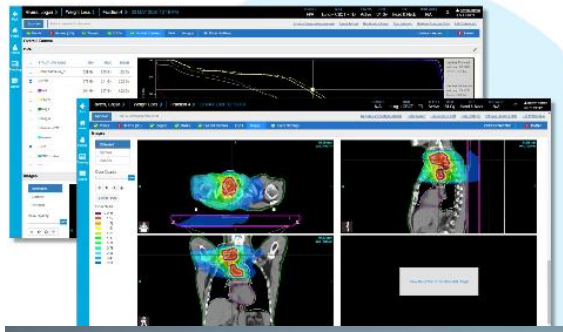
Nina Cavalli et al. J Appl Clin Med Phys. 2024;25:e14156

Commercial software

SUN NUCLEAR

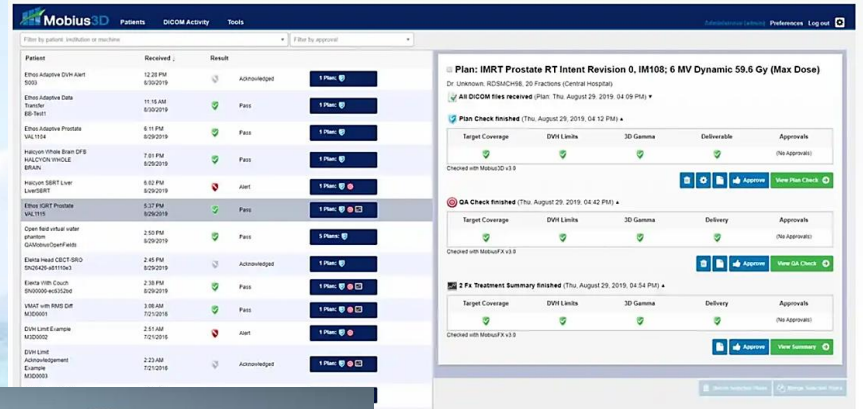
SunCHECK® Patient

- **Plan Quality Checks**
  Automated Physics & Dosimetric Checks
- **Secondary Dose Calcs**
  Complete 3D Analysis & Dose Comparisons
- **Pre-Treatment QA**
  Phantomless & Array-Based Flexibility
- **In-Vivo Monitoring**
  Verify & Track Dose Through Treatment Course



Mobius3D

Comprehensive platform for patient quality assurance.

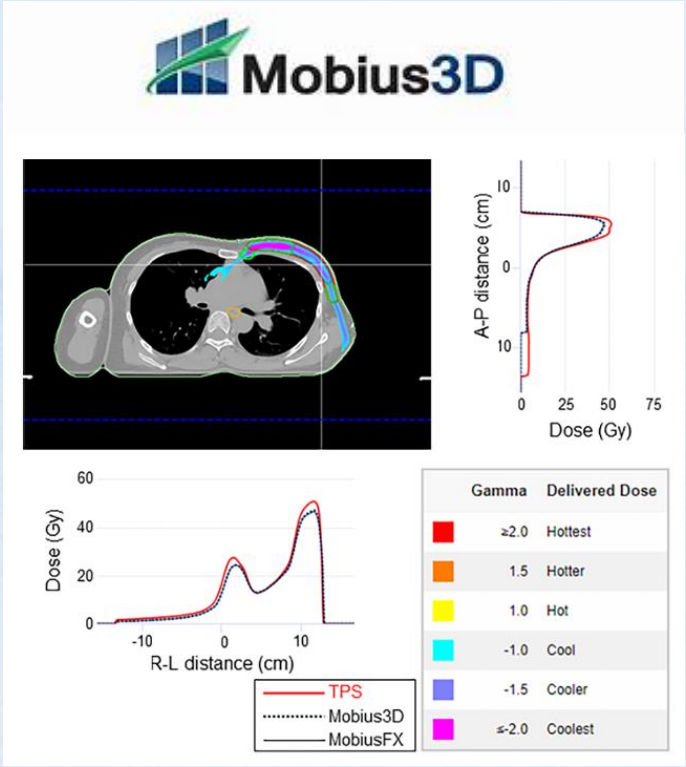


RadCalc

RadCalc is your complete patient-centric 3D QA solution. A suite of tools that seamlessly integrates into existing workflows providing end-to-end QA throughout the patient's journey.

Mobius3D

- Mobius3D is a secondary independent dose verification system.
  - Commissioning needed:
    - Percentage depth dose
    - Off-axis ratio
    - Output factor
    - Dosimetric leaf gap
    - CT HU



Clinical experience with machine log file software for volumetric-modulated arc therapy techniques

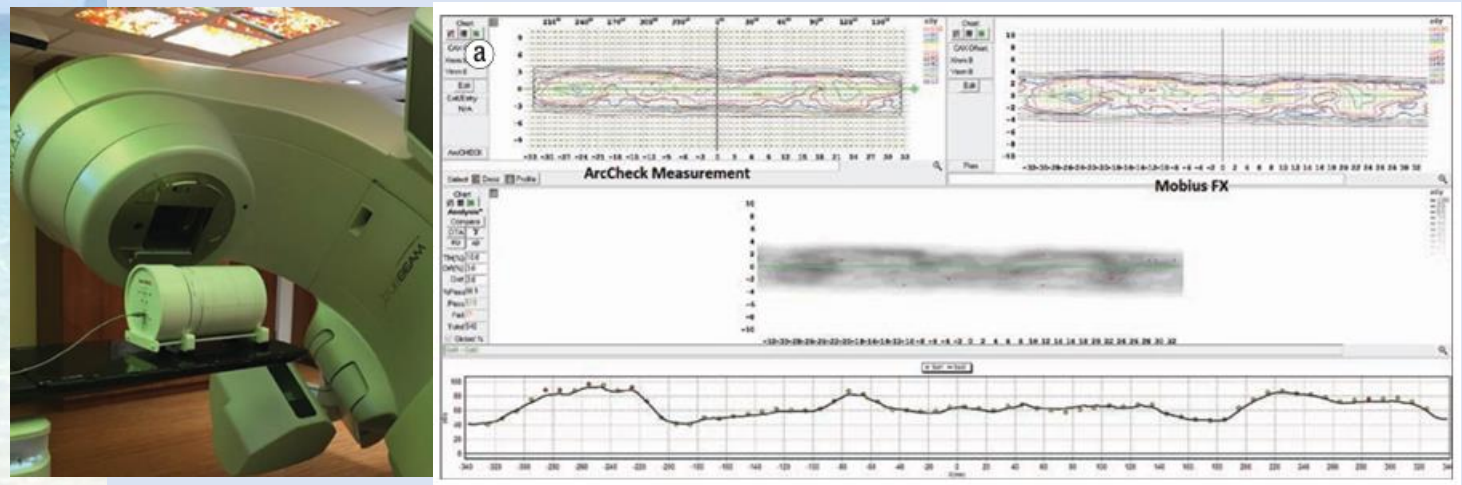
Luis Alberto Vazquez-Quino, PhD, Claudia Ivette Huerta-Hernandez, PhD, and Dharanipathy Rangaraj, PhD

Proc (Bayl Univ Med Cent) 2017;30(3):276–279

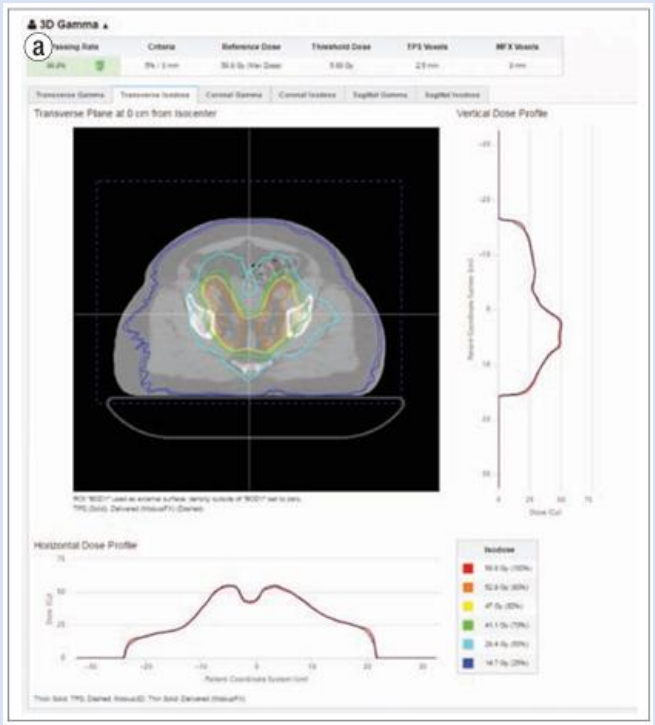
Luis Alberto Vazquex-Quino et al. Proc (Bayl Univ Med Cent) 2017

Software-based evaluation

- Compare between Mobius FX , ArcCheck and TPS
  - 30 VMAT plans (2 or 3 Arcs)
  - Varian TrueBeam linear accelerator
  - Gamma criteria: 3%/3 mm and 2%/2 mm



ArcCheck



Mobius FX

Luis Alberto Vazquex-Quino et al. Proc (Bayl Univ Med Cent) 2017

Software-based evaluation

VMAT QA gamma comparison results among Mobius FX, ArcCheck measurement

ArcCheck vs Eclipse		Mobius FX vs Eclipse	
3%3mm	2%2mm	3%3mm	2%2mm
99.48%	96.80%	99.96%	98.80%

Luis Alberto Vazquex-Quino et al. Proc (Bayl Univ Med Cent) 2017

Software-based: Attention

- Small field size
- Lung and bone region
- Density override
- Type of accelerator
- Off-axis
- Dosimetric leaf gap correction factor

Yair Hillman et al.

Jihun Kim et al. Physica Medica 74 (2020)

Yuji Nakaguchi et al. Japanese Society of Radiological Technology and Japan Society of Medical Physics 2019

Reference: Software-based PSQA

Is it still necessary to perform measured based pre-treatment patient-specific QA for SRS HyperArc treatments?

Nina Cavalli[1] | Elisa Bonanno[1] | Giuseppina R. Borzi[1] | Alessia D'Anna[2] | Martina Pace[1] | Giuseppe Stella[2] | Lucia Zirone[1] | Carmelo Marino[1]

J Appl Clin Med Phys. 2024;25:e14156.

Evaluation of a novel secondary check tool for intensity-modulated radiotherapy treatment planning

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JournAL oF APPLIEd cLInIcAL MEdIcAL PHYSIcS, VoLuME 15, nuMBEr 5, 2014

Validation of secondary dose calculation system with manufacturer-provided reference beam data using heterogeneous phantoms

Yuji Nakaguchi[1] · Yuya Nakamura[1] · Yohei Yotsuji[1]

Japanese Society of Radiological Technology and Japan Society of Medical Physics 2019

Detailed evaluation of Mobius3D dose calculation accuracy for volumetric-modulated arc therapy

Jihun Kim[a], Min Cheol Han[a], Eungman Lee[b], Kwangwoo Park[a], Kyung Hwan Chang[a], Dong Wook Kim[a], Jin Sung Kim[a,*], Chae-Seon Hong[a,*]

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[b] *Department of Radiation Oncology, Ewha Womans University College of Medicine, Seoul, South Korea*

Physica Medica 74 (2020) 125–132

Assessment of the Dosimetric Performance of the Mobius3D against Portal Dose Measurements in Patient-specific Quality Assurance

Yasmine Joy M. Labagnoy, Sornjarod Oonsiri[1], Mananchaya Vimolnoch[1], Sakda Kingkaew[1]
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Clinical performance of FractionLab in patient-specific quality assurance for intensity-modulated radiotherapy : a retrospective study

Se An Oh[1], Sung Yeop Kim[2], Jaehyeon Park[1], Jae Won Park[1], Ji Woon Yea[1]
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Med Sci 2022;39(2):108-115

The 2023 Biomedical Engineering International Conference (BMEiCON-2023)

Utilizing Statistical Process Control Analysis for Calculation-Based Patient-Specific Quality Assurance in Online Adaptive Radiotherapy

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The 2023 Biomedical Engineering International Conference (BMEiCON-2023)

Thai Medical Physicist Society

Abstract:
This study utilized statistical process control analysis to determine the gamma passing rate limits in calculation-based patient-specific quality assurance (PSQA) using Mobius3D. A total of 50 PSQA Mobius3D plans were derived from 168 online adaptive plans and constructed into a control chart, calculating upper control limit (UCL), center line (CL), and lower control limit (LCL) values. The PSQA process quality was further evaluated through the process capability index. The results revealed that the LCL values for the 3%/2mm, 2%/2mm, and 1%/1mm criteria were 91.66, 76.34, and 12.13, respectively. The corresponding C pm values were 1.149, 1.098, and 0.760, while the C pml values were 2.430, 2.297, and 1.612. These findings indicated a high PSQA process quality for the 3%/2mm and 2%/2mm criteria, evidenced by consistent and favorable C pm and C pml values. However, assessing the PSQA process quality for the 1%/1mm criterion raised concerns. The low LCL values suggested potential issues with precision and accuracy in evaluating treatment plans. Additionally, the lack of consistency between the C pm and C pml values further indicated that the 1%/1mm criterion might not be suitable for clinical use with Mobius3D. Considering these results, caution should be exercised when employing the 1%/1mm criterion in the PSQA process. It is essential to prioritize accuracy and reliability to ensure the delivery of high-quality patient-specific treatment plans in radiotherapy. This study offers valuable insights for optimizing the PSQA process with Mobius3D and enhancing patient care and safety.

Gamma passing rate
3%2mm ≥ 92%

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Virtual patient-specific quality assurance in online adaptive radiotherapy using deep learning-based 2-dimensional information

Kampheang Nimjaroen

Major advisor Dr. rer. Medic. Chirasak Khamfongkhruea

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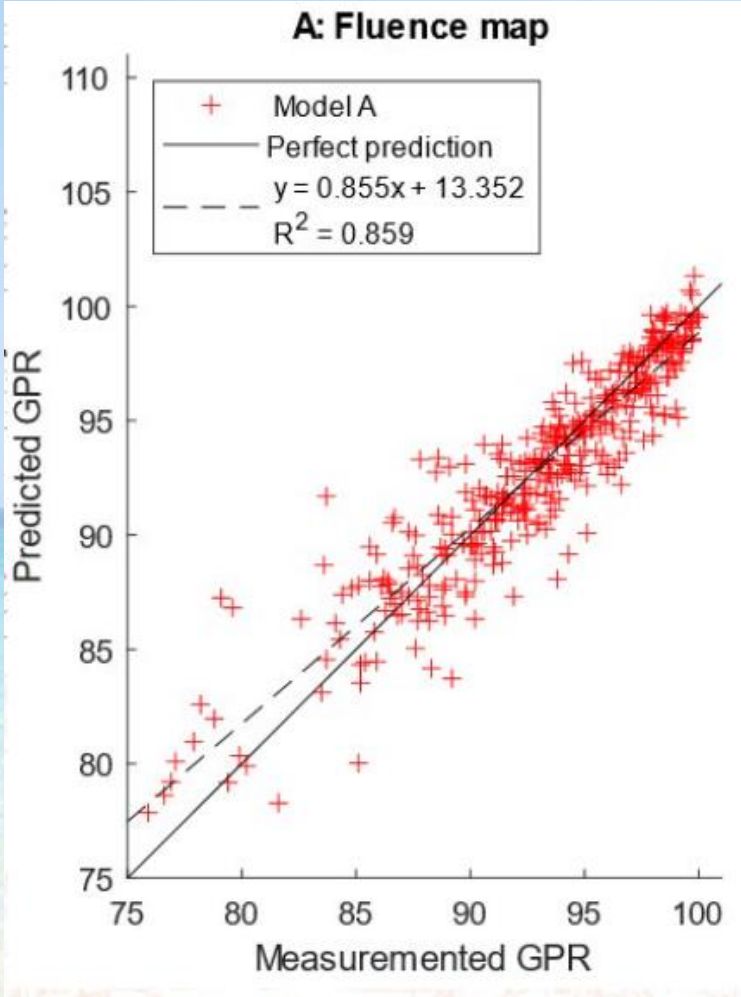
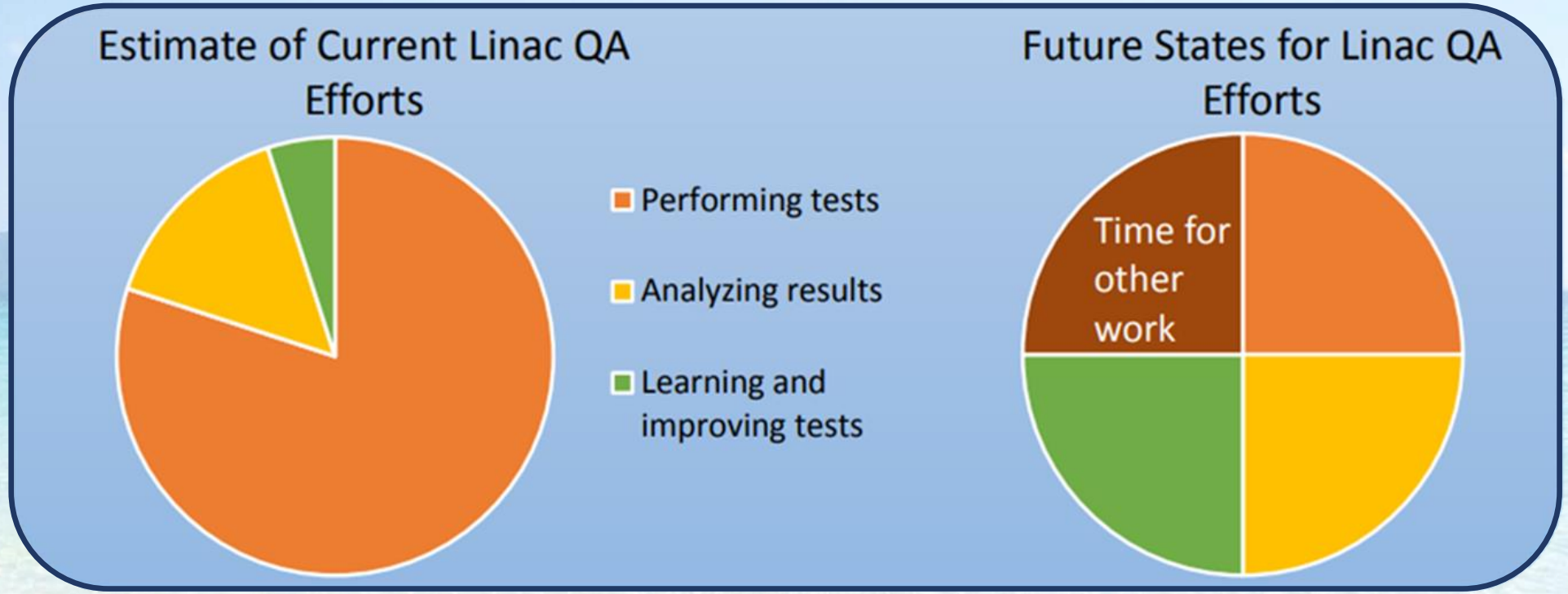
Princess Srisavangavadhana College of Medicine, Chulabhorn Royal Academy



- 2D information can be used to create prediction model for virtual-based PSQA.
- MLC velocity map enhance the prediction model in combined with fluence maps.

This approach has the potential to establish the foundation for virtual PSQA in the online Adaptive radiation therapy treatment process

Kampheang Nimjaroen



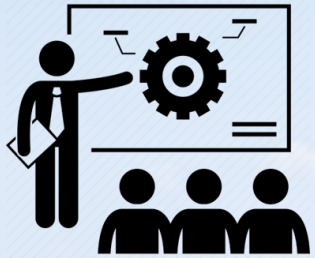
Schmidt et al. J Appl Clin Med Phys 2021; 22:6:26–34

Implementation

Brainstorm

Identify which process to automate?
- Monotonous work
- Large data
- Time consuming

Choose the automation tool



Commissioning and Training

Evaluation
- Accuracy
- Limitation

Validation
- Accuracy
- Update

Thank you