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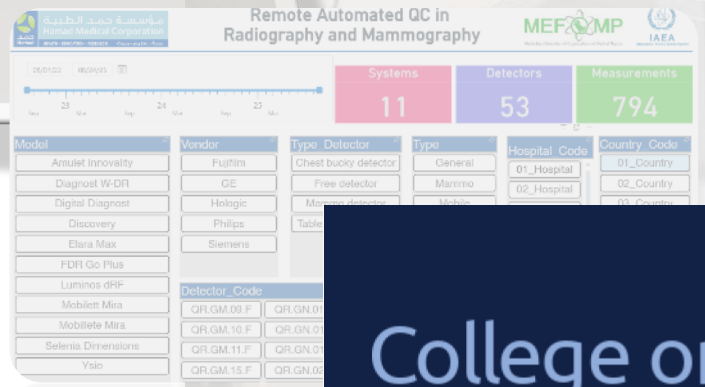
Remote and Automated Quality Control for General Radiography and Mammography



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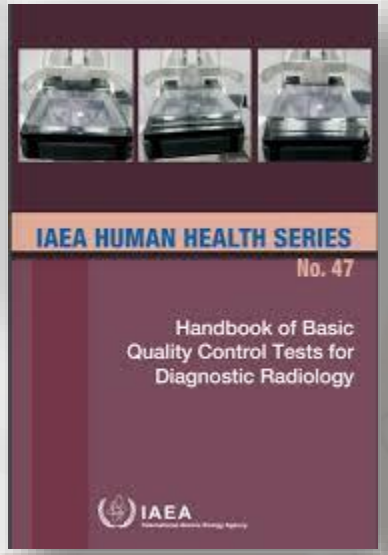
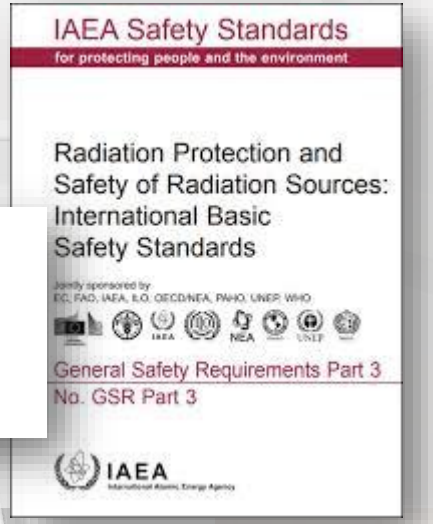
Introduction

- Central role of diagnostic imaging
- Need for strict QC
- International frameworks: IAEA, ACR, IEC





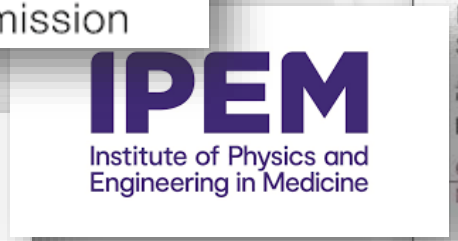


Image Quality Phantoms with Software

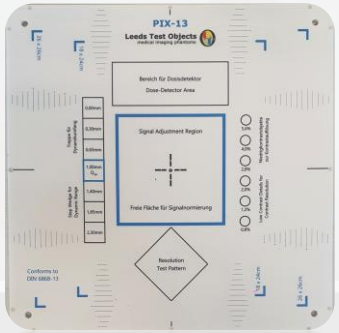
General X-ray
Mobile X-ray

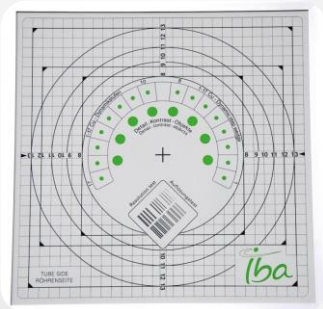
Fluoroscopy systems

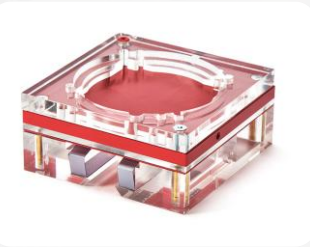
CT scanners

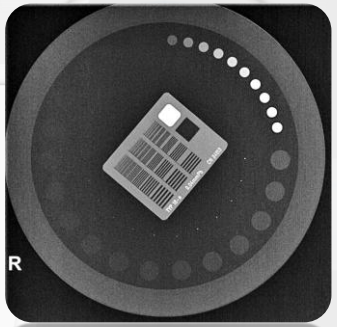
CBCT units

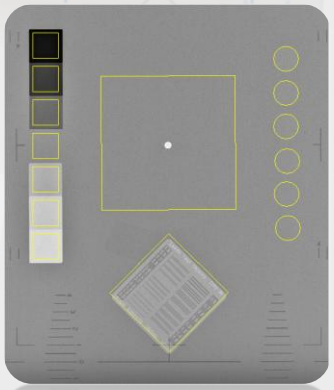
Dental units

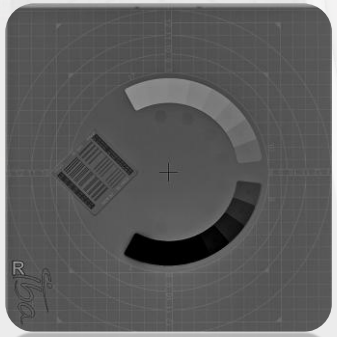


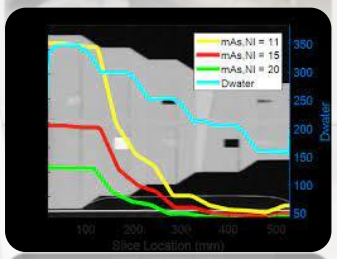


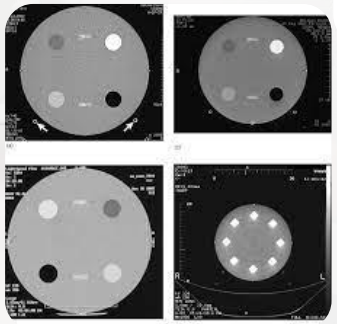


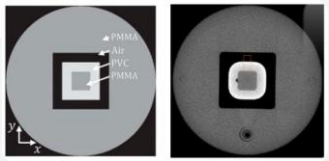


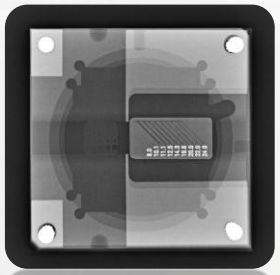


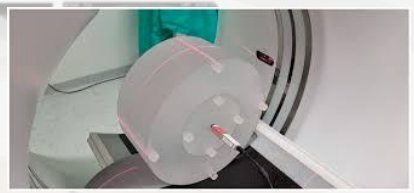










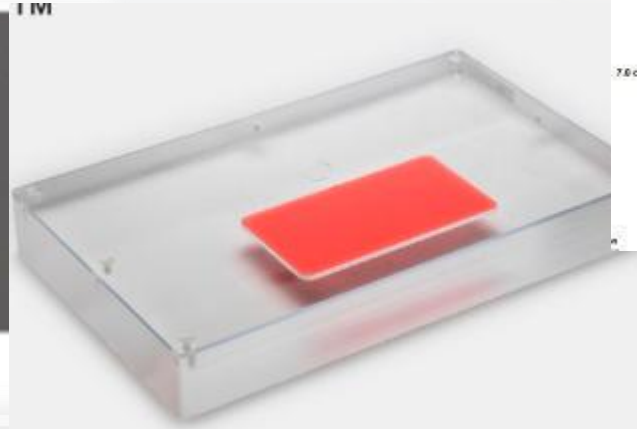


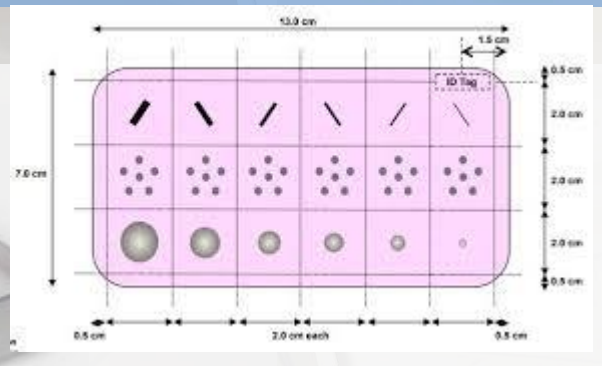
QC in Radiography- Objectives

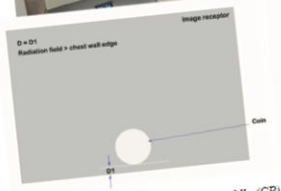
- Ensure accurate image acquisition (output, IQ, Doses …)
- Maintain reproducible image quality
- Detect equipment malfunction early

QC ensures minimal patient dose and consistent image quality…

QC in Mammography







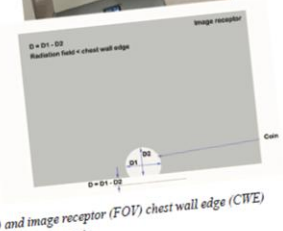


Figure 4.1 *Assessment of compression paddle (CP) and image receptor (FOV) chest wall edge (CWE) misalignment using the larger coin*

Precautions and Caveats

Recommended Performance Criteria & Corrective Action

References

Notes

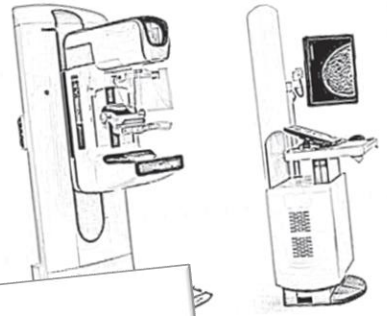
be identified and eliminated.

- Large inaccuracies in indicated AGD values must be corrected before clinical use.
- For DBT mode, an additional correction factor is required for calculating AGD (depends on the mammography unit and the swing angle). However, it is very close to 1 and can be ignored at first approximation (EUREF 2018).

Figure 4.7 *Schematic diagram of geometric setup for AGD measurements*

4

MAMMOGRAPHY SYSTEMS (2D & DBT UNITS)



partments, women's clinics

ergy X-rays to produce 2D images provides information about breast gross pathology. Mammography is e breast cancer, as well as to evaluate reast lesions. Mammography is very

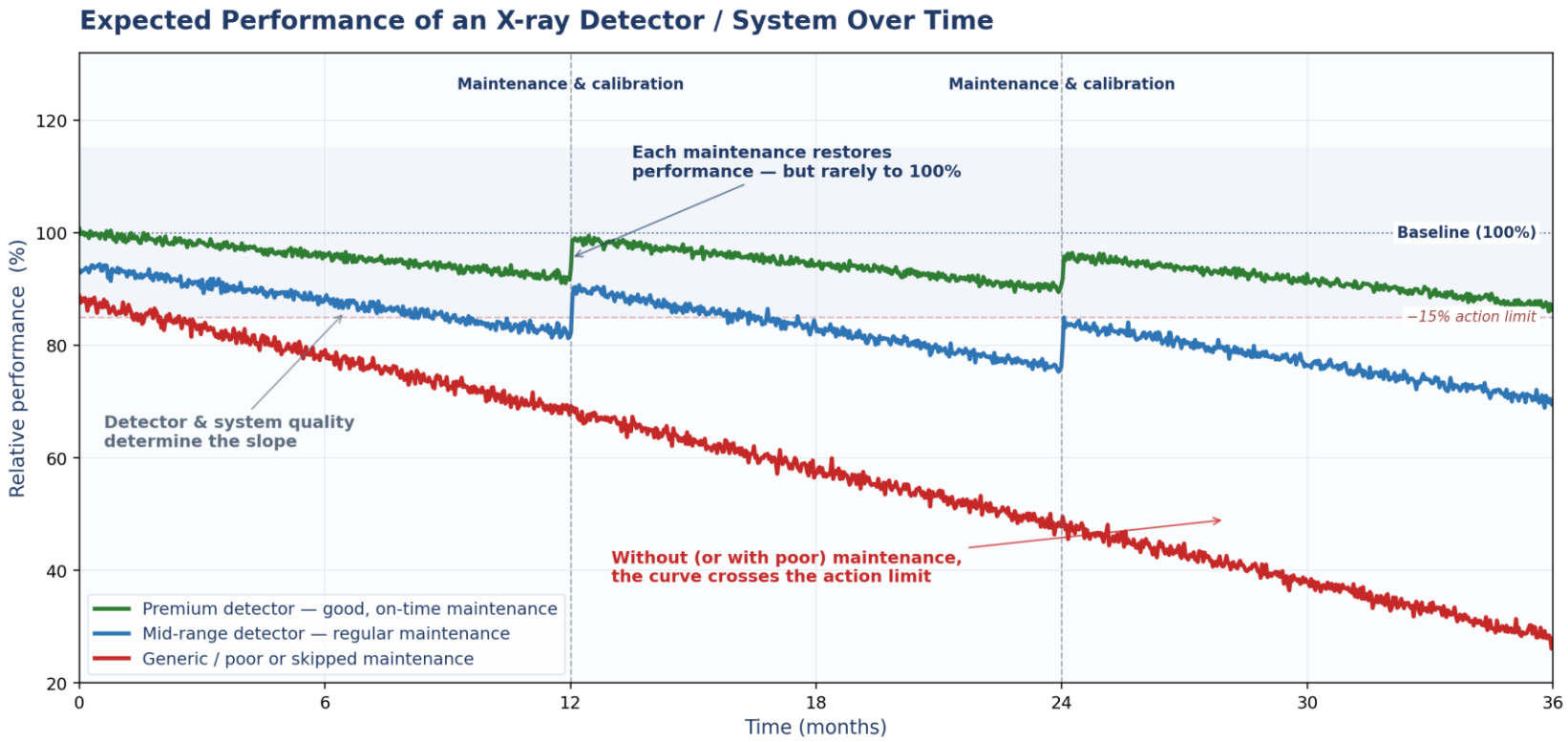
9

Figure 4.3 *The MFM sensor positioning for exposure factors measurements*

Table 4. Remedial levels for mammography QC tests

Procedure code	QC test group	Physical parameter	Level of expertise	Priority	Remedial level	Ref.
MM-01	Technical assessment	Alignment X-ray & light field	B	1	Deviations (L+R) or (anterior + chest edge) should be within ±2% of SID.	ACR (2018)
MM-02		Alignment X-ray field/edges of the image receptor (FOV)	B	1	Deviations should be within ±2% of SID.	ACR (2018)
MM-03		Alignment of compression paddle and image receptor CWE	A	1	Deviations should be within ±1% @ SID.	ACR (2018)
MM-04		Compression force accuracy	B	2	Deviations between measured and displayed compression should be within ±20 N.	IPEM (2005)
MM-11	Generator & tube	kVp accuracy	B	1	Deviations should be within ±5%.	ACR (2018)
MM-12		kVp repeatability	B	1	Coefficient of variation should be ≤2%.	ACR (2018)
MM-13		Output repeatability	B	1	Coefficient of variation should be ≤5%.	GAEC (2019a)
MM-17		Beam quality (HVL)	B	1	≥ 0.3 mm Al @ 30 kV.	ACR (2018)
MM-21	Image quality	Image quality: ACR DM Phantom (old ACR Phantom)	A	1	Fiber score ≥ 2 (≥ 4) Speck group score ≥ 3 (≥3) Mass score ≥ 2 (≥ 3) Distance of wax insert 70 ± 14 mm (N/A) SNR[D] ≥ 40, CNR ≥ 2 (N/A)	ACR (2018)
MM-22		Spatial resolution	B	1	For 2D: ≥ 4 lp/mm @ contact mode ≥ 6 lp/mm @ magnification mode For DBT: ≥ 2 lp/mm @ contact mode	ACR (2018)
MM-31	AEC	AEC thickness tracking (compensation)	A	1	SNR ≥ 40 @ 4 cm For other thicknesses, SNR should be within ±15% of baseline.	ACR (2018)
MM-41	Dosimetry	Average glandular dose (AGD): ACR phantom (2D & DBT)	A	1	Should not exceed 3 mGy @ single cranio-caudal view of the ACR DM phantom (2D and DBT).	ACR (2018)
MM-42		Displayed AGD accuracy	B	1	Unit-indicated AGD should be within ±25% of calculated AGD.	ACR (2018)
MM-43		Average examination doses (AGD)	B	1	≤ International, National, or Local DRLs	EUREF (2018)

Expected Performance of an X-ray Detector / System Over Time



KEY PRINCIPLES

01 Quality sets the slope

Premium detectors and X-ray tubes degrade slowly; lower-grade units degrade noticeably faster — even with identical workload.

02 Maintenance restores — partially

Calibration and service push performance back up, but the recovered peak is almost always lower than the previous one. Recovery is asymptotic, not full.

03 Skipped or poor maintenance is unbounded

If maintenance is late or done badly, the curve keeps falling, eventually crossing the −15% action limit. The platform flags this before it happens.

WHAT THIS MEANS FOR THE QC PROGRAMME

- Long monitoring windows naturally reveal a downward trend — that alone is not a failure signal. **What matters is the slope and whether it is being arrested by maintenance.**
- A detector that recovers to ~95–98 % of baseline after each service is behaving normally; a unit that recovers to <80 % needs investigation. **Compare the recovered peaks, not just the absolute level.**
- When the platform flags a Confirmed drift or Strong drift, the question is rarely "is something wrong?" — it is **"is the maintenance cycle short enough for this asset class?"**

Drift in one metric points to a specific physical sub-system

Image-quality, exposure-technique, and dose metrics each have a different physical origin. When the platform flags drift, read the metric back to the component most likely responsible.

Detector wear

AFFECTED METRICS

SNR ↓
CNR ↓
MTF ↓
d'L ↓
d's ↓

Photo-conductor / scintillator ageing, dead pixels, gain drift. Image quality fades first — exposure factors look normal.

ACTION

Detector calibration → flat-field correction → consider end-of-life if not recoverable.

X-ray tube output

AFFECTED METRICS

SNR ↓
CNR ↓
MTF ↓

Anode pitting, filament thinning, falling tube output. Looks like a detector problem — but mAs may rise to compensate.

ACTION

Output measurement (mGy/mAs), HVL check, tube replacement schedule.

AEC mis-calibration

AFFECTED METRICS

mAs ↑ or ↓
ED drifts
DAP drifts

AEC over- or under-exposes for the same phantom. mAs moves directly while IQ may stay flat — that mismatch is the tell.

ACTION

AEC calibration on standard phantom; verify density/photo-cell selection.

Generator fault

AFFECTED METRICS

kVp instability
mAs jitter
Reproducibility ↓

High-voltage generator drift, ripple, or switching errors. Exposure parameters become inconsistent between successive exposures.

ACTION

Generator service — kVp/mAs accuracy + reproducibility tests.

DIAGNOSTIC SHORTCUT

IQ drops + exposure constant → **detector or tube** · mAs moves but IQ flat → **AEC** · kVp / mAs jitter → **generator**

Implementation of a Remote and Automated QC Programme for Radiography and Mammography Equipment

- Overview of the IAEA framework for remote and automated Quality Control (QC) in radiography and mammography.

Purpose of the Report

- Provide a framework for frequent QC testing without on-site CQMP presence
- Enable remote oversight by CQMPs
- Promote early detection of performance issues
- Reduce patient dose and maintain image quality

Scope

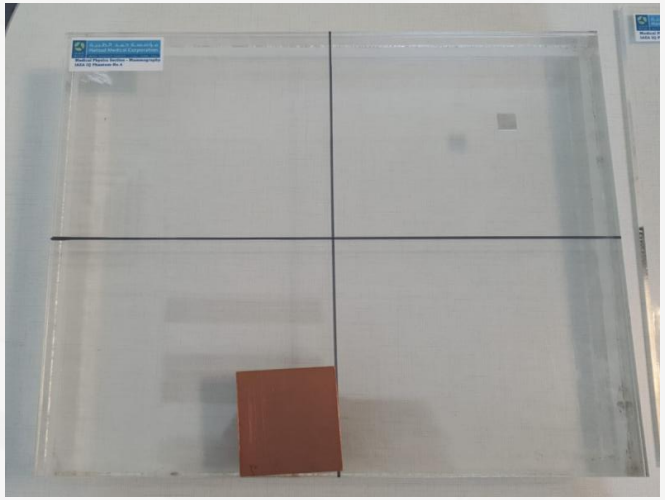
- Applies to conventional planar imaging (radiography and mammography)
- Directed towards CQMPs, technologists, radiologists, regulators, and administrators
- Supports both digital and screen–film syste

Background

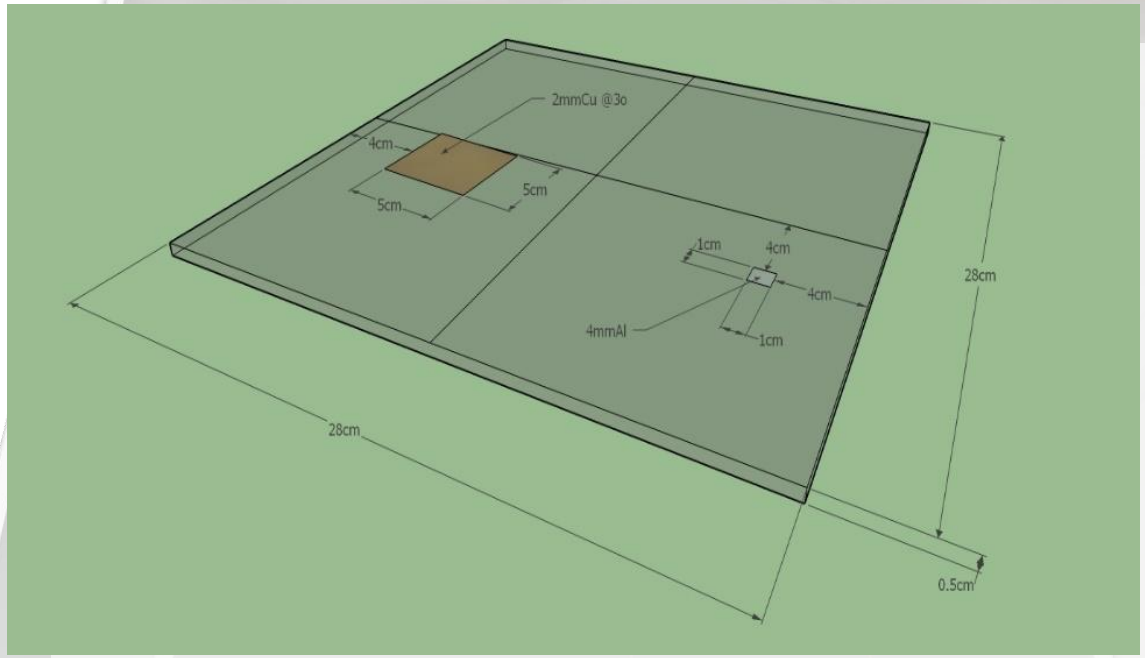
- QC often underperformed worldwide
- Lack of CQMPs and resources limit QA implementation
- Annual checks insufficient to detect short-term equipment issues

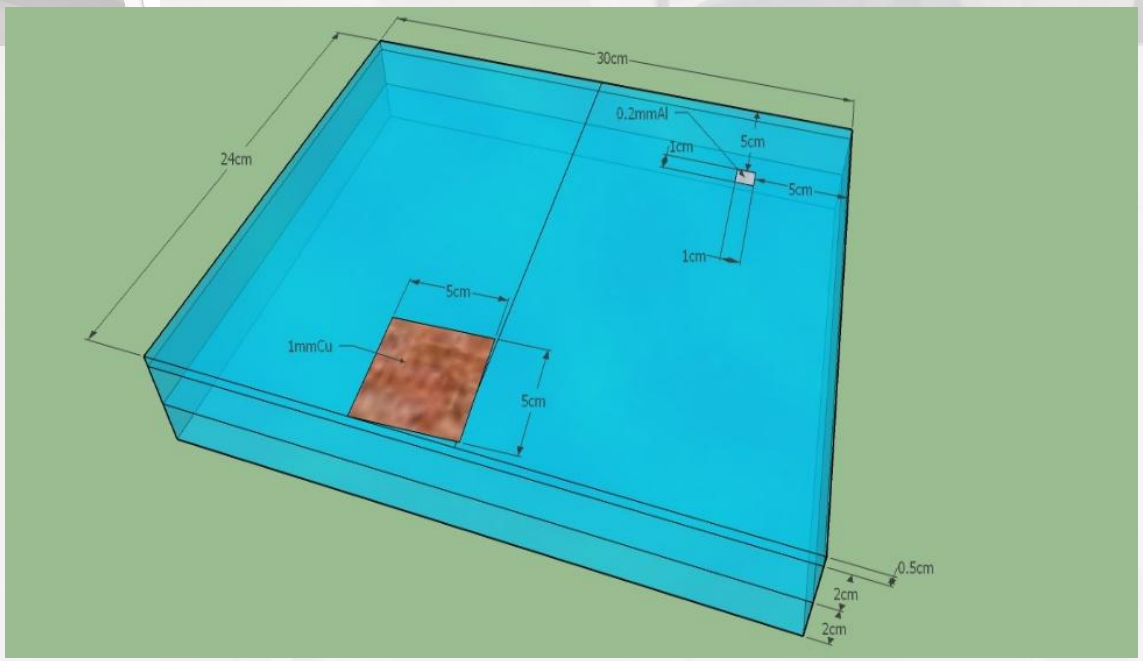
Framework of Remote QC

- Simple, low-cost phantoms for radiography and mammography
- Automated image analysis software
- Centralized data collection and review
- Local or remote implementation options



Automated Image Quality Monitoring System





- Attenuator plate of 2 mm thick copper (10 cm×10 cm)

- Target plate consisting of a carrier and inserts:

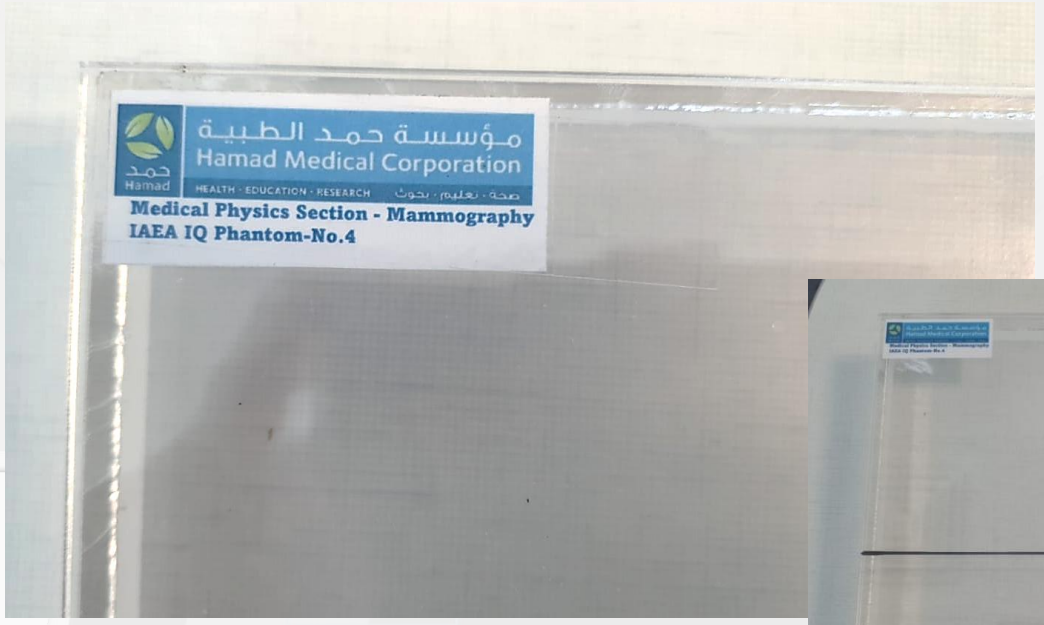
❖ ● *5 mm thick PMMA (28 cm × 28 cm);*
❖ ● *4 mm thick aluminium (1 cm × 1 cm);*
❖ ● *2 mm thick copper (5 cm × 5 cm).*

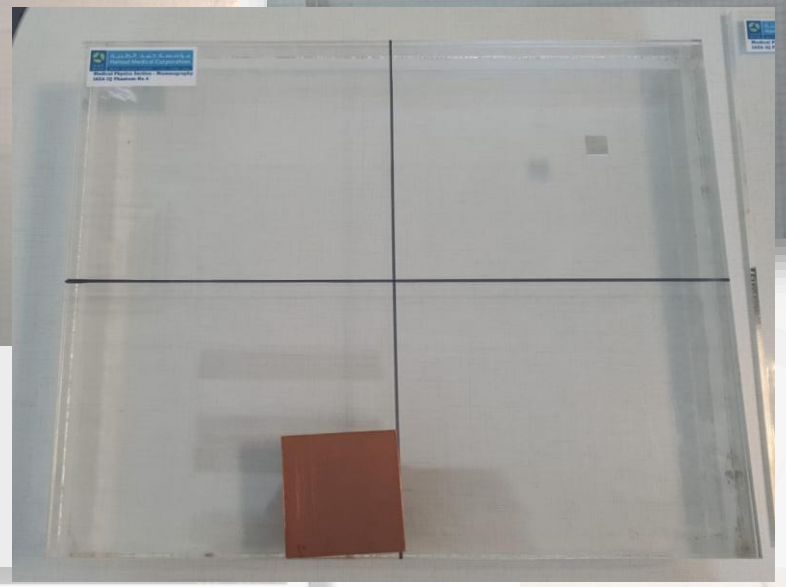
- Attenuator plate of 4 cm thick PMMA (24 cm × 30 cm);

- Target plate consisting of a carrier and inserts:

❖ *5 mm thick PMMA (24 cm × 30 cm);*
❖ *0.2 mm thick aluminium (1 cm × 1 cm);*
❖ *1 mm thick copper (5 cm × 5 cm).*

Automated Image Quality Monitoring System



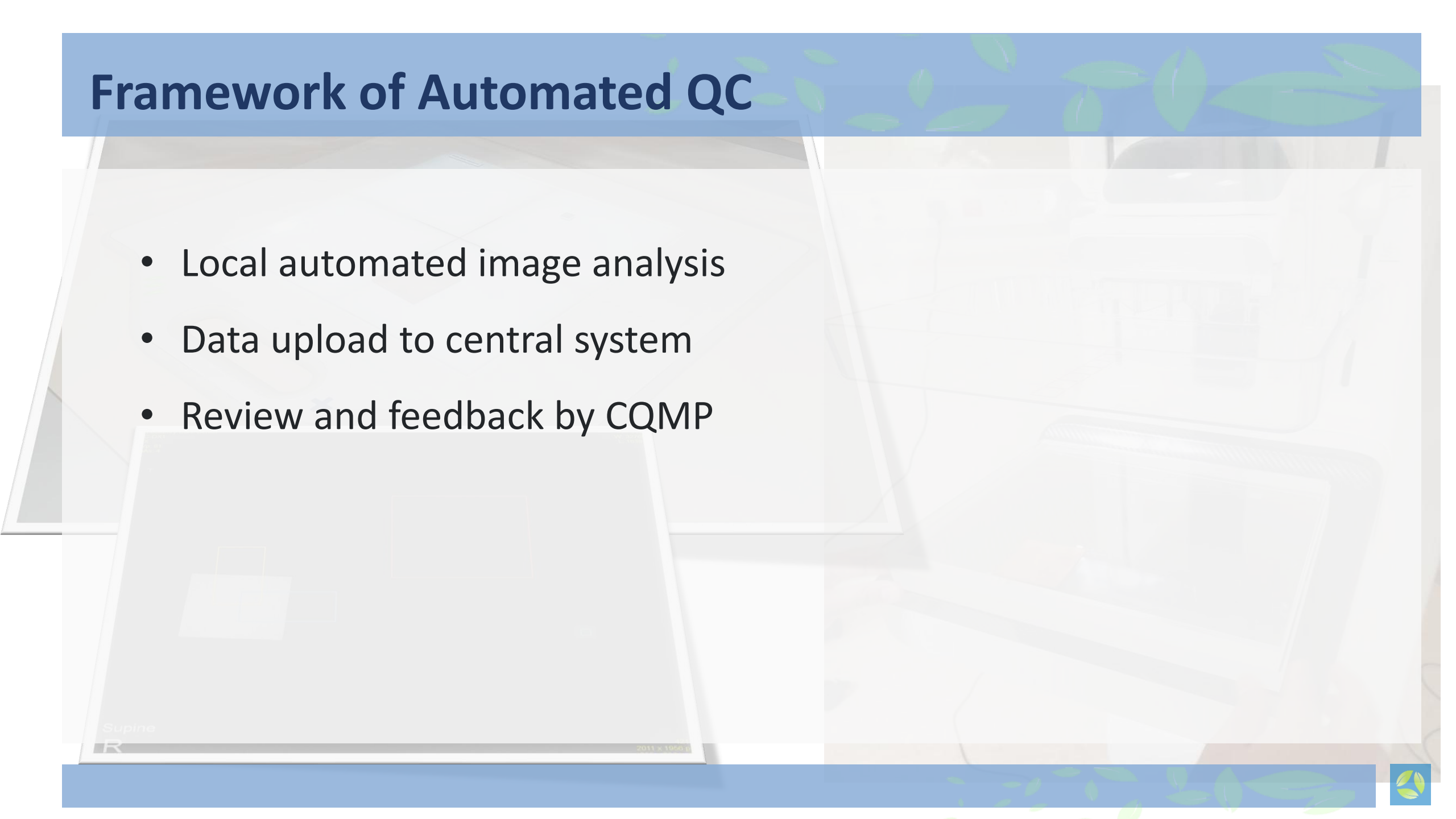


Framework of Remote QC

- Local image acquisition and verification
- Artefact detection
- Image upload to central system
- Centralized analysis and reporting

Framework of Automated QC

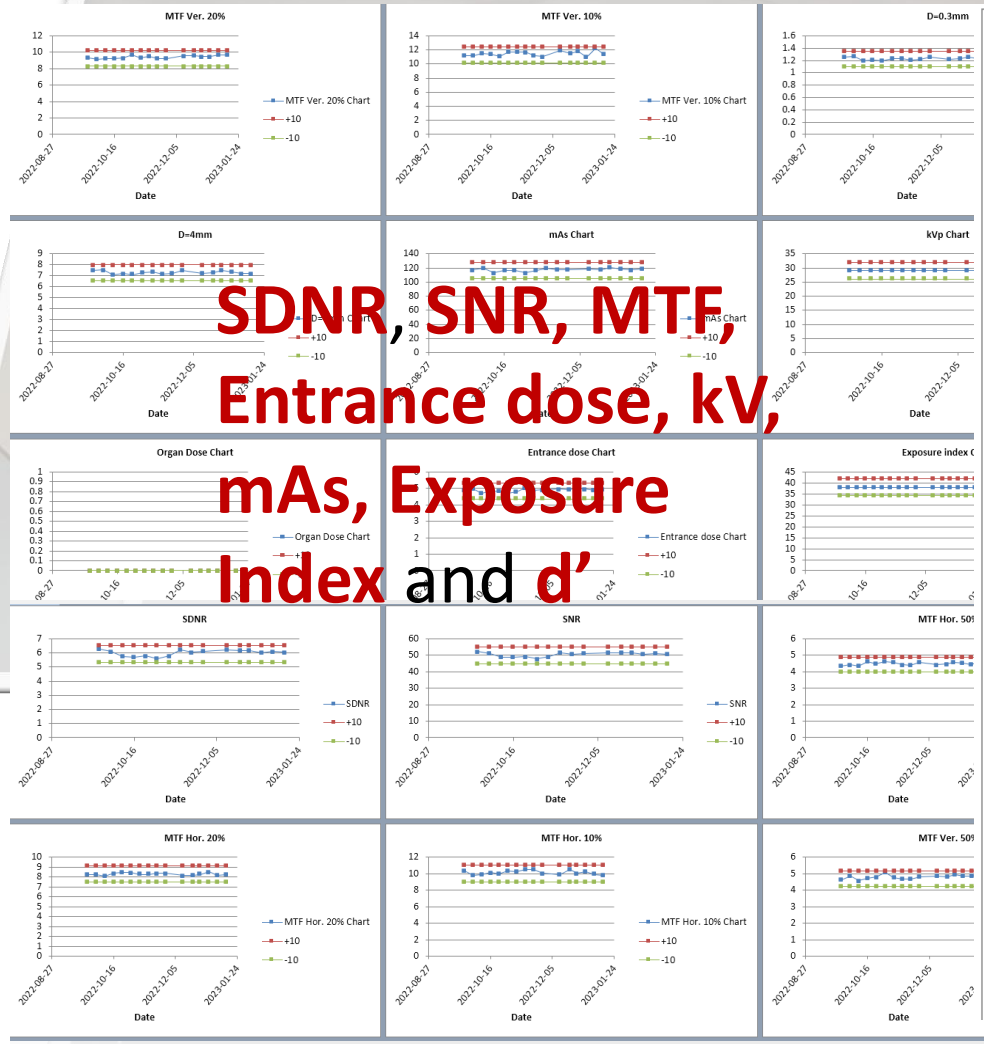
- Local automated image analysis
- Data upload to central system
- Review and feedback by CQMP



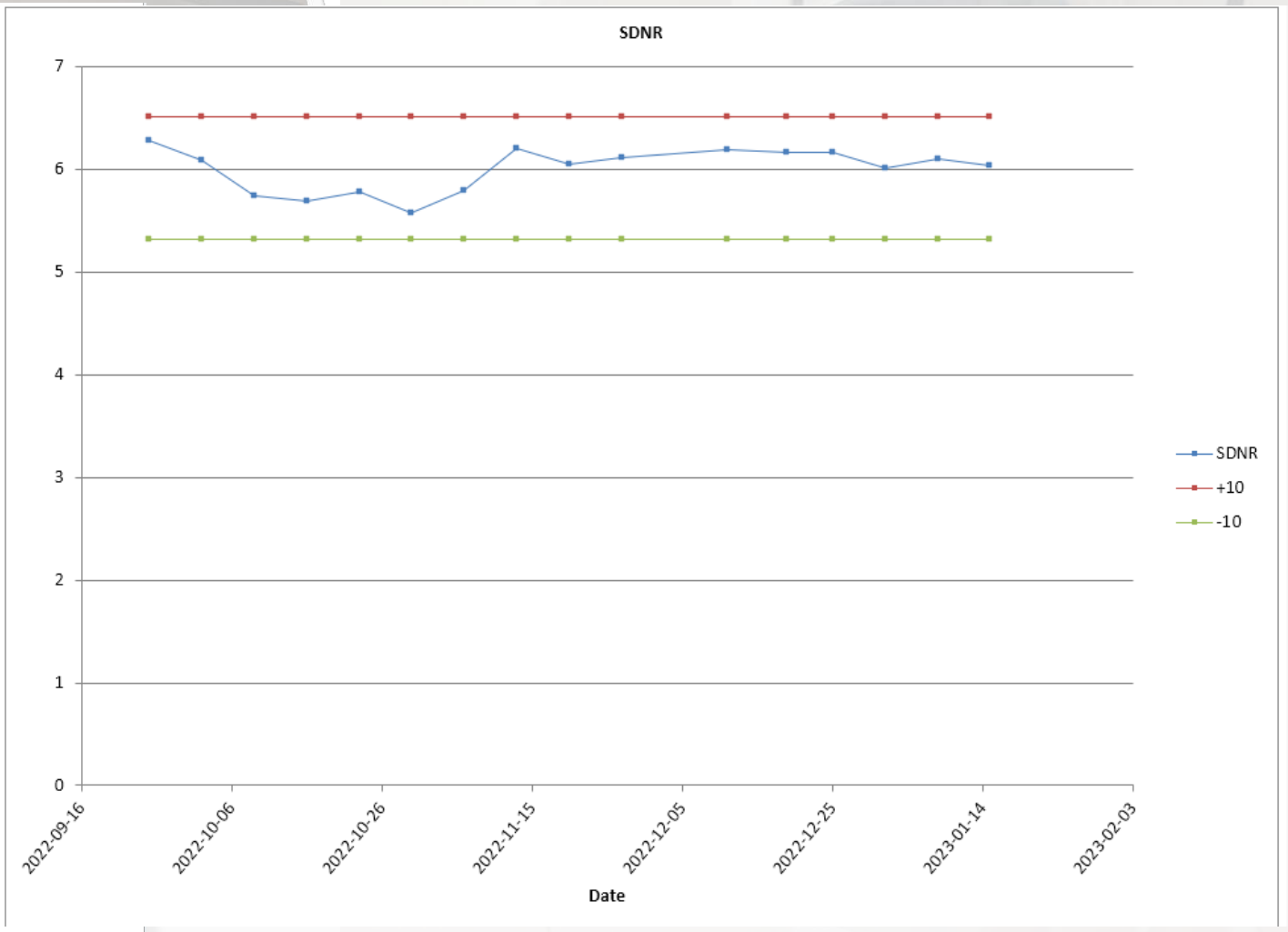
Benefits of Remote & Automated QC

- More frequent monitoring than annual checks
- Resource-efficient in areas with limited CQMPs
- Supports benchmarking and consistency
- Early fault detection reduces downtime

Automated Image Quality Monitoring System



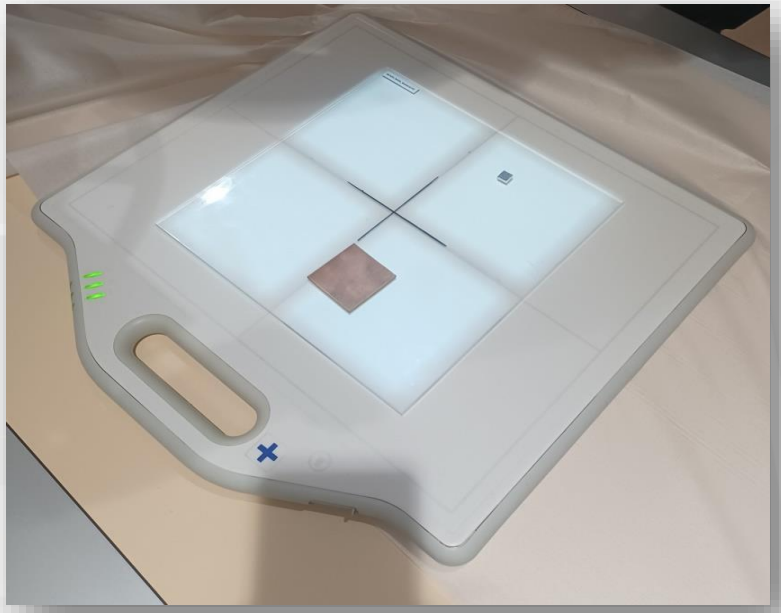
SDNR, SNR, MTF, Entrance dose, kV, mAs, Exposure Index and d'



Implementation Requirements – Human Resources

- Medical radiation technologists – perform tests and upload data
- CQMPs – oversight, analysis, corrective actions
- IT staff – ensure connectivity and security
- Service engineers – maintenance

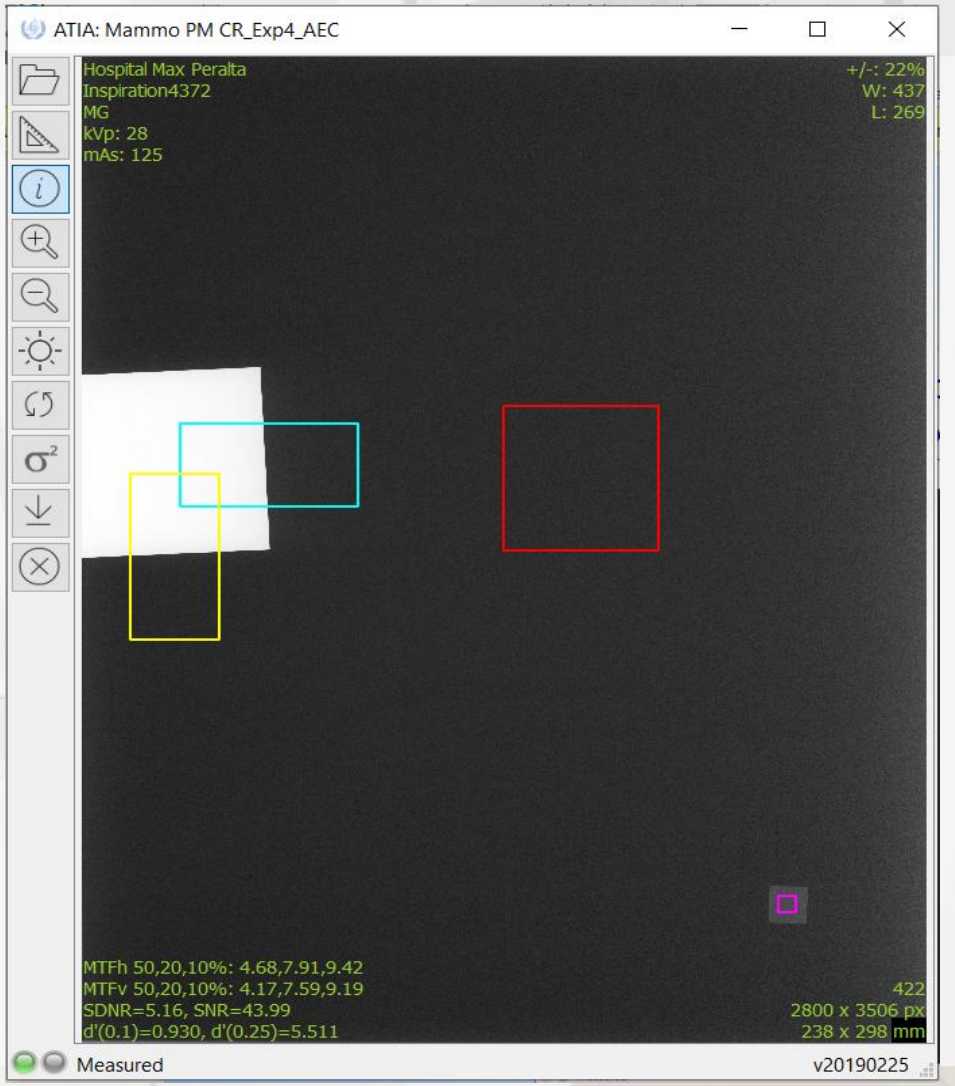
Automated Image Quality Monitoring System



Automated Image Quality Monitoring System (ATIA software)

$$\mathrm{CNR} = \frac{\frac{I_{\text{target}} - I_{\text{background}}}{I_{\text{background}}}}{\frac{\sigma_{\text{background}}}{I_{\text{background}}}} = \frac{I_{\text{target}} - I_{\text{background}}}{\sigma_{\text{background}}} = \mathrm{SdNR}.$$

Study of **SDNR**, **SNR, MTF, Entrance dose, kV, mAs, Exposure Index** and **d'**



Implementation Requirements – IT Infrastructure

- Options for sites with and without image transmission
- Central data repository with secure access
- Unique IDs for facilities and systems
- Data protection measures

Central Data Repository

- Small, medium, or large-scale implementation
- Tracks performance over time
- Allows national or regional benchmarking

Financial Considerations

- QC programs are cost-effective long term
- Initial investment in phantoms, software, and training
- Budget for ongoing staff time and infrastructure

Conclusion

- Remote and automated QC enhances patient safety and image quality
- Facilitates consistent performance monitoring
- Cost-effective and scalable for varied healthcare settings
- Promotes a culture of quality in imaging

Supporting Materials

- Software user manual
- Phantom blueprints
- Statistical tools
- Image quality metrics guide
- DICOM data reference
- Pilot study results
- QC data forms

Automated Image Quality Monitoring System

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MAMMOGRAPHY UNIT:
HOLOGIC-SELENIA DIMENSIONS

IAEA QC METHODOLOGY USER MANUAL

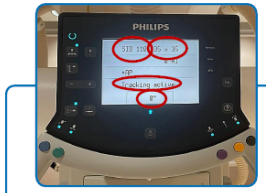
1.1. PHILIPS TB

Phantom Description:

The IAEA radiography phantom consists of:

- A 5 mm thick PMMA plate with dimensions 28 cm x 28 cm, with a 2 mm thick Copper square (5 cm x 5 cm) and a 4 mm thick Aluminum square (1 cm x 1 cm) that lay flat (glued) on the PMMA plate at specific locations.
- A 2 mm thick Copper attenuator plate (or two plates of 1 mm each) with dimensions 17 cm x 17.5 cm.

Phantom Setup:

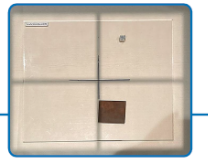


- Select **Tracking active.**
- Set the Tube Head angle to **0°**.
- Adjust the Source-to-Image Distance (**SID**) to **110** cm.
- Set the field size to **35 cm x 35 cm.**

1

- Confirm that the grid is in place and that this grid is the one used in table X-ray examinations (e.g. Abdomen).
- The focal distance, ratio and line density are usually **fo110 cm, R12** and **N40,** respectively.
- For this QC test the same grid should be always used.

2



- Position the phantom on the table and use the crosswire & the crossmarkers to align the phantom in the light field center.
- Ensure that the Cu square of the phantom is positioned at the *right bottom* side of the light field.
- ***Note:*** *The field size can be extended up to the image receptor dimensions (e.g. 43 cm x 43 cm).*

3

- Insert the 2 mm Cu attenuator into the sliding railings positioned under the collimator assembly to cover the entire field size.
- You may need to rotate the Cu plate by 90° to fit within the railings.
- **Make sure that the Cu plate is secured.**

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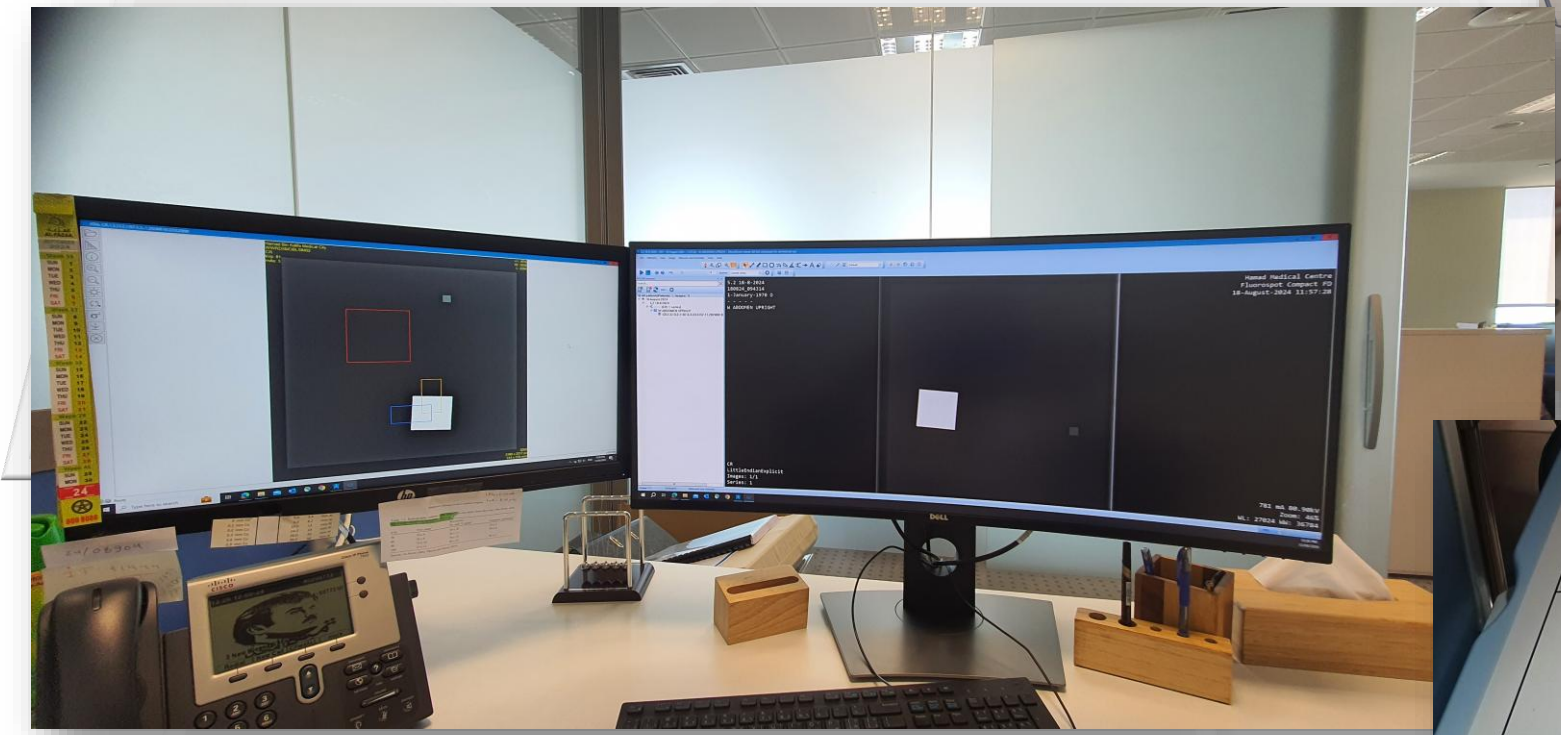
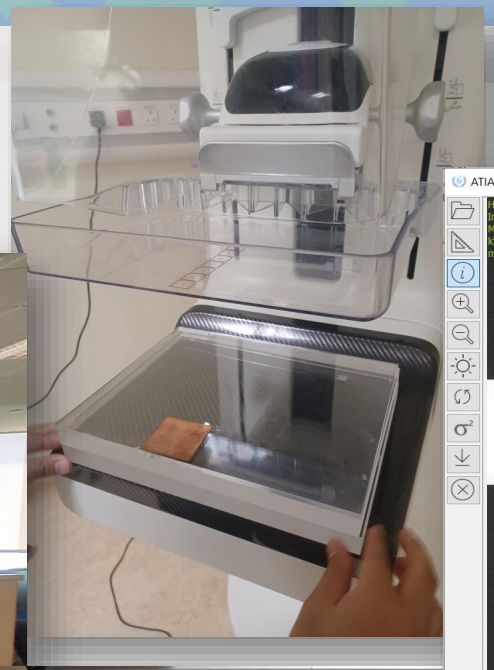
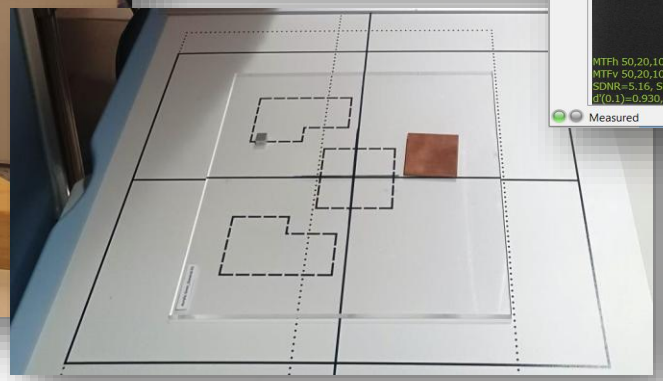
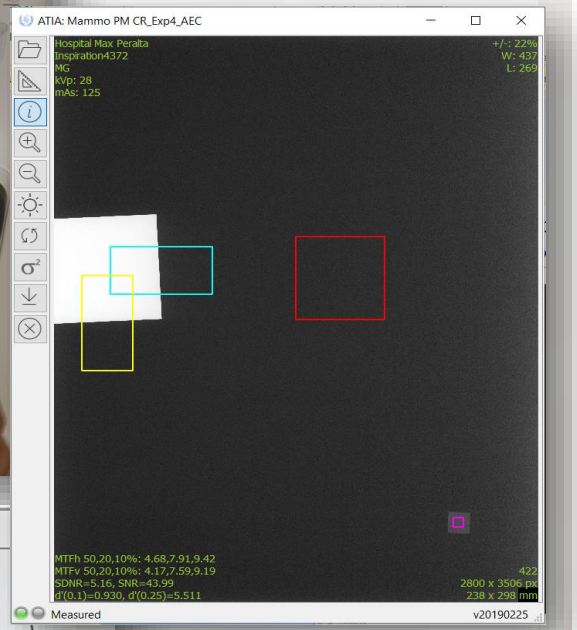
Automated Image Quality Monitoring System









ATIA Software Development and Updates

ATIA software

- This tool will automatically calculate the following variables:
  - **SDNR**
  - **CNR**
  - **MTF**
  - **d'.**

Each variable can later be tracked over time to see its behaviour in order to take corrective actions as needed.

- ATIA can extract and report relevant tags (e.g. kVp, mA, s, exposure index) from the DICOM header of image that can be used to supplement the information from the QC image.

Research and Publications

Received: 20 November 2023 | Revised: 27 December 2023 | Accepted: 3 January 2024

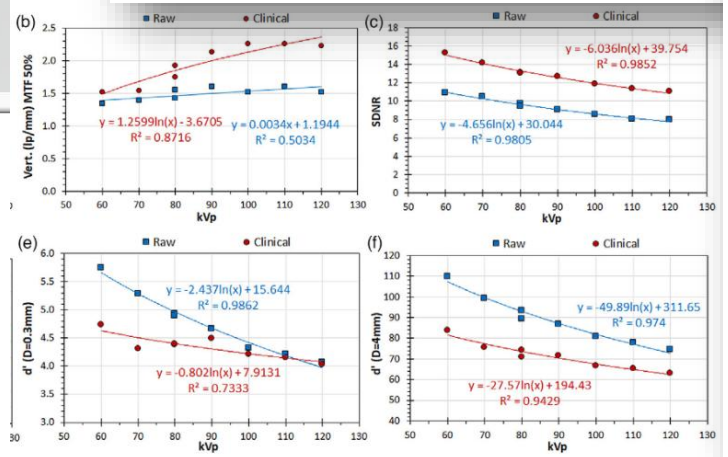
DOI: 10.1002/acm2.14285

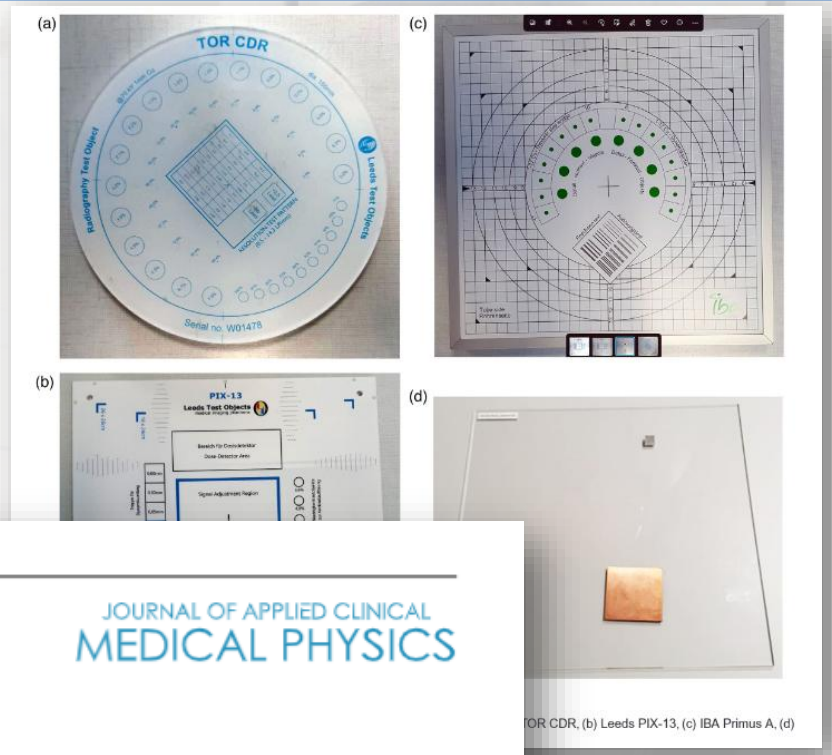
JOURNAL OF APPLIED CLINICAL MEDICAL PHYSICS

IMAGING PHYSICS

Automatic image quality evaluation in digital radiography using for-processing and for-presentation images

Ioannis A. Tsalafoutas[1] | Shady AlKhazzam[1] | Virginia Tsapaki[2] | Mohammed Hassan Kharita[1]





TOR CDR, (b) Leeds PIX-13, (c) IBA Primus A, (d)

Received: 27 June 2022 | Revised: 27 September 2022 | Accepted: 1 October 2022

DOI: 10.1002/acm2.13823

JOURNAL OF APPLIED CLINICAL MEDICAL PHYSICS

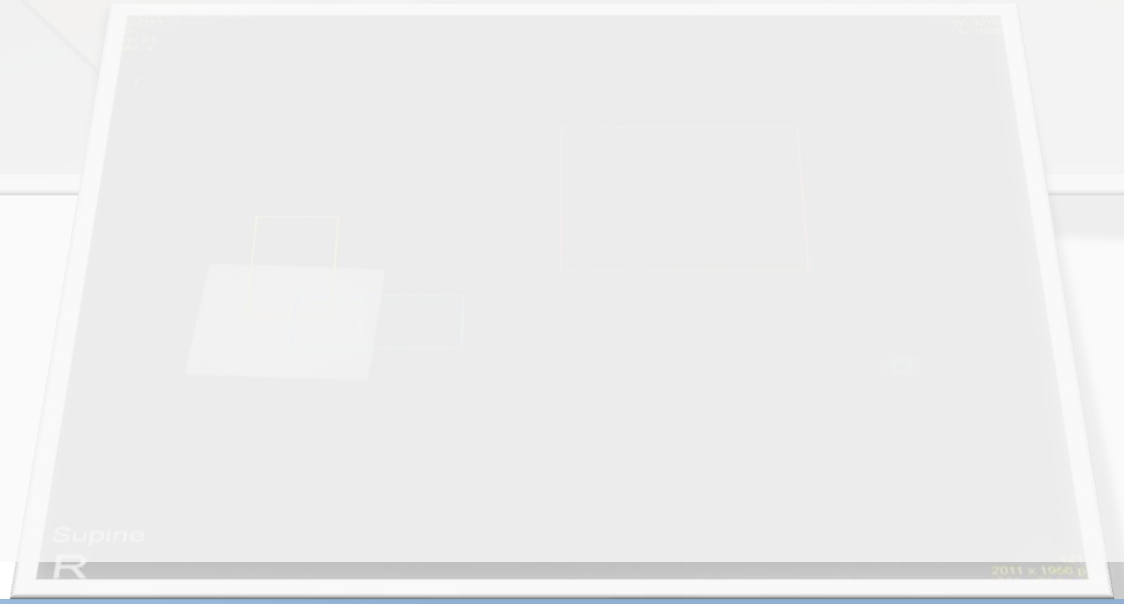
MEDICAL IMAGING

Digital radiography image quality evaluation using various phantoms and software

Ioannis A. Tsalafoutas[1] | Shady AlKhazzam[1] | Virginia Tsapaki[2] | Huda AlNaemi[1,3] | Mohammed Hassan Kharita[1]

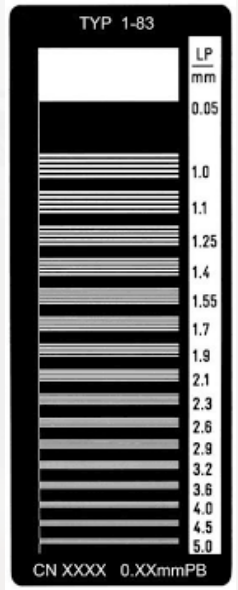
Testing & Reporting

- Phantom design with **PMMA**, **copper**, and **aluminium** targets
- Measures MTF, CNR, SNR, and detectability index (d’)
- Consistent positioning, collimation, and exposure parameters

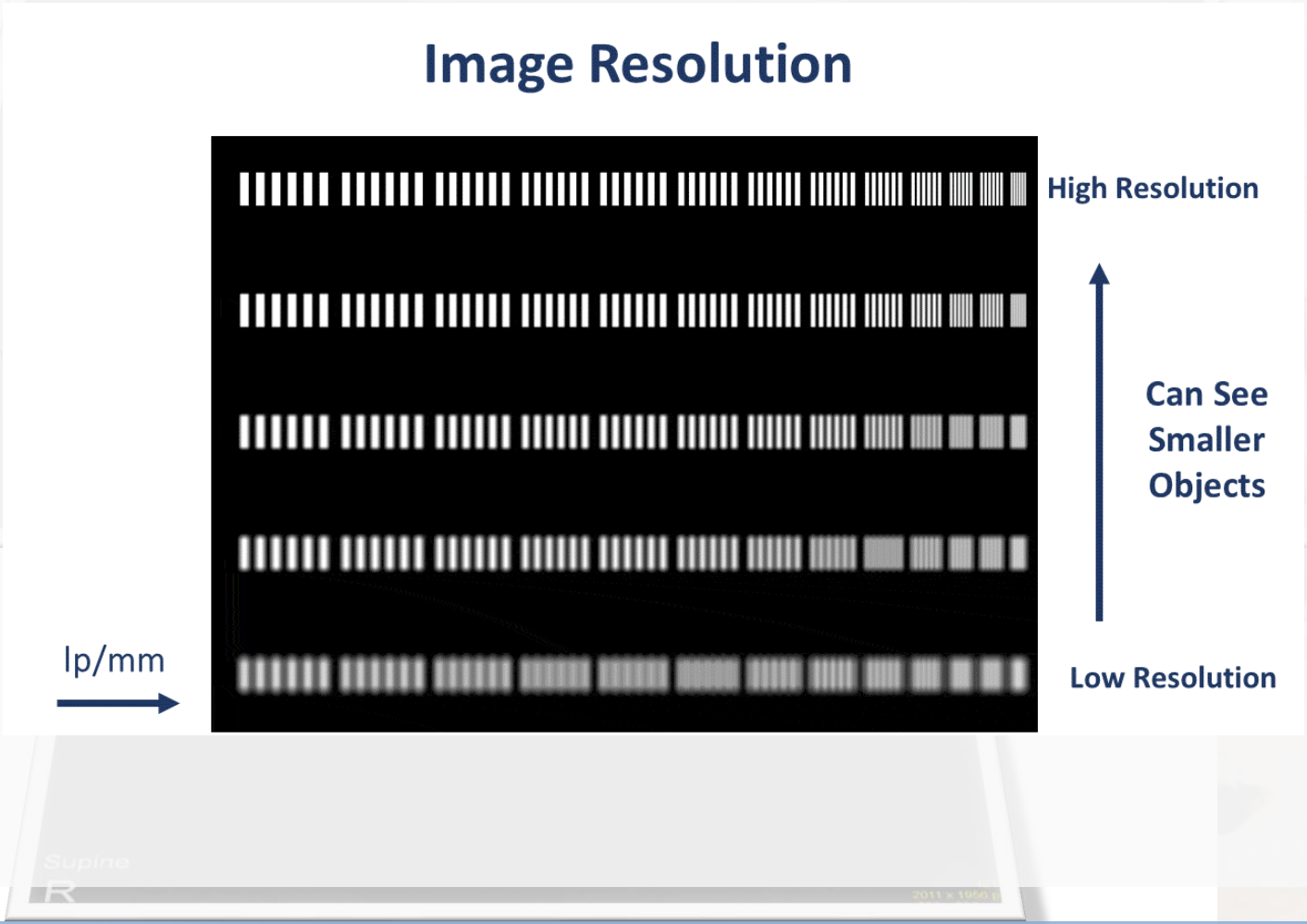


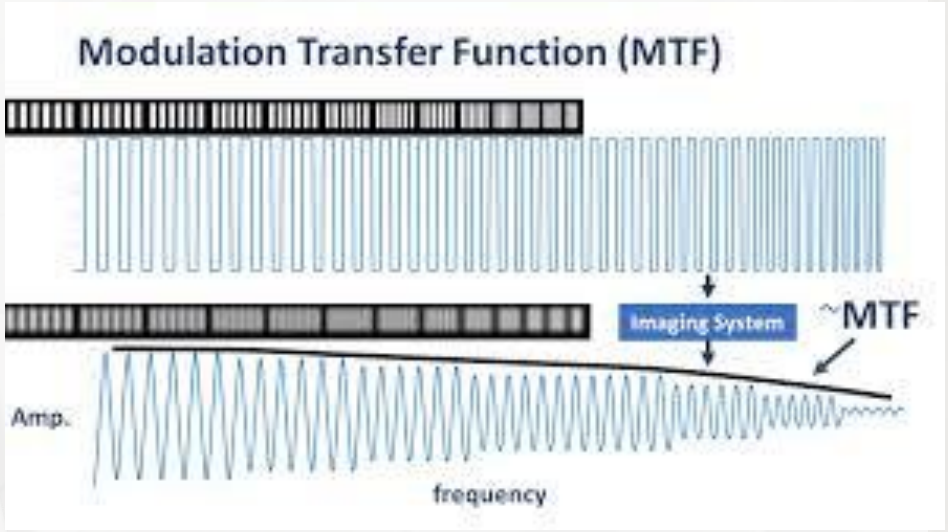
Modulation Transfer Function (MTF)

- Measures ability to reproduce contrast at different spatial frequencies
- Obtained from Edge-Spread Function (ESF) → Line-Spread Function (LSF) → Fourier Transform
- Higher MTF = better resolution
- Common benchmarks: **MTF** at **50%** and 10%

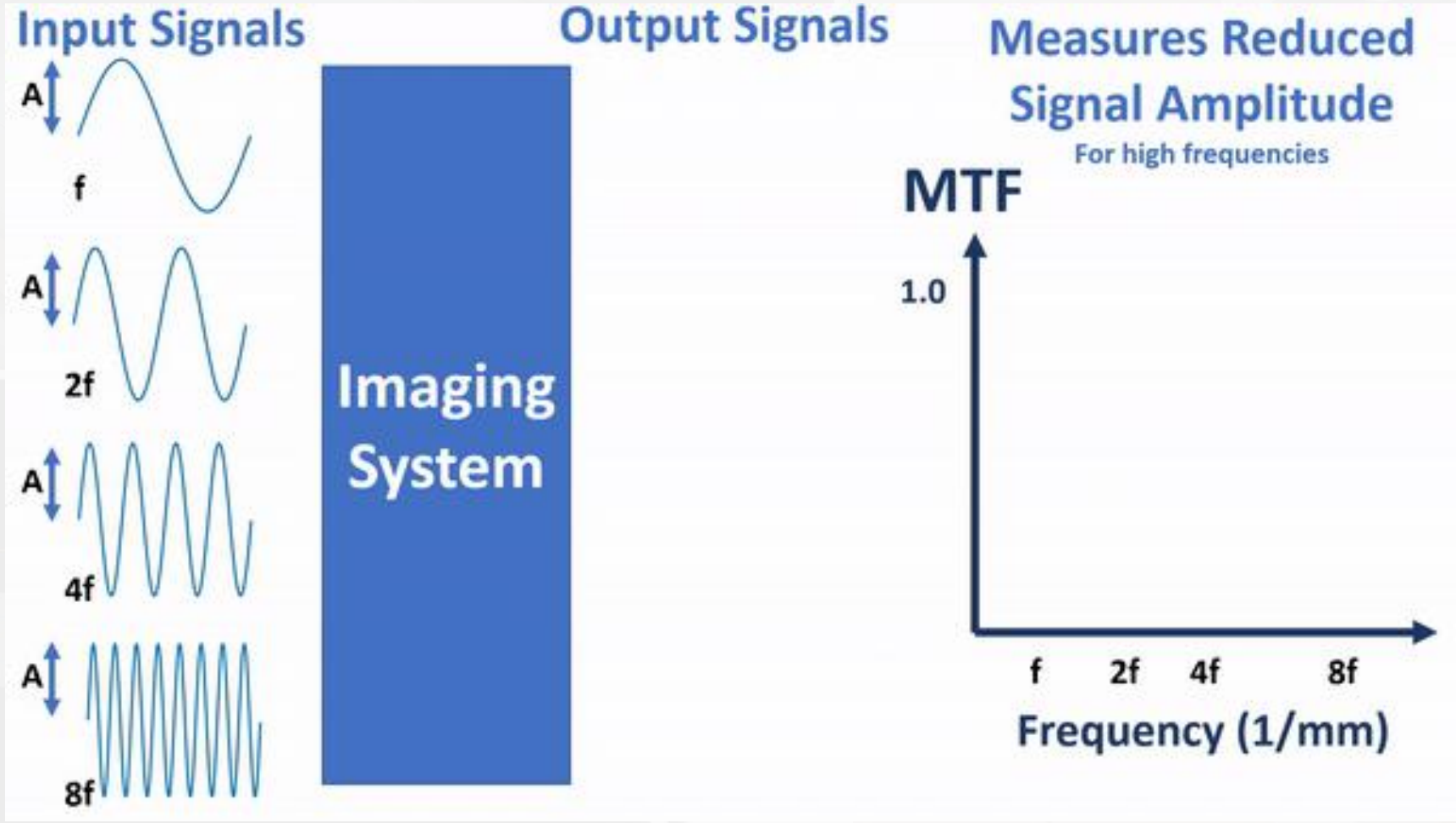


Modulation Transfer Function (MTF)

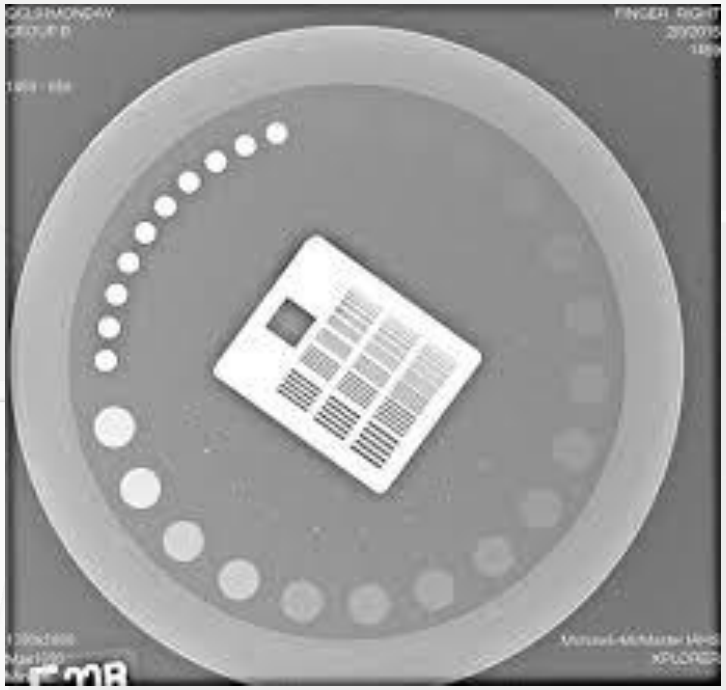


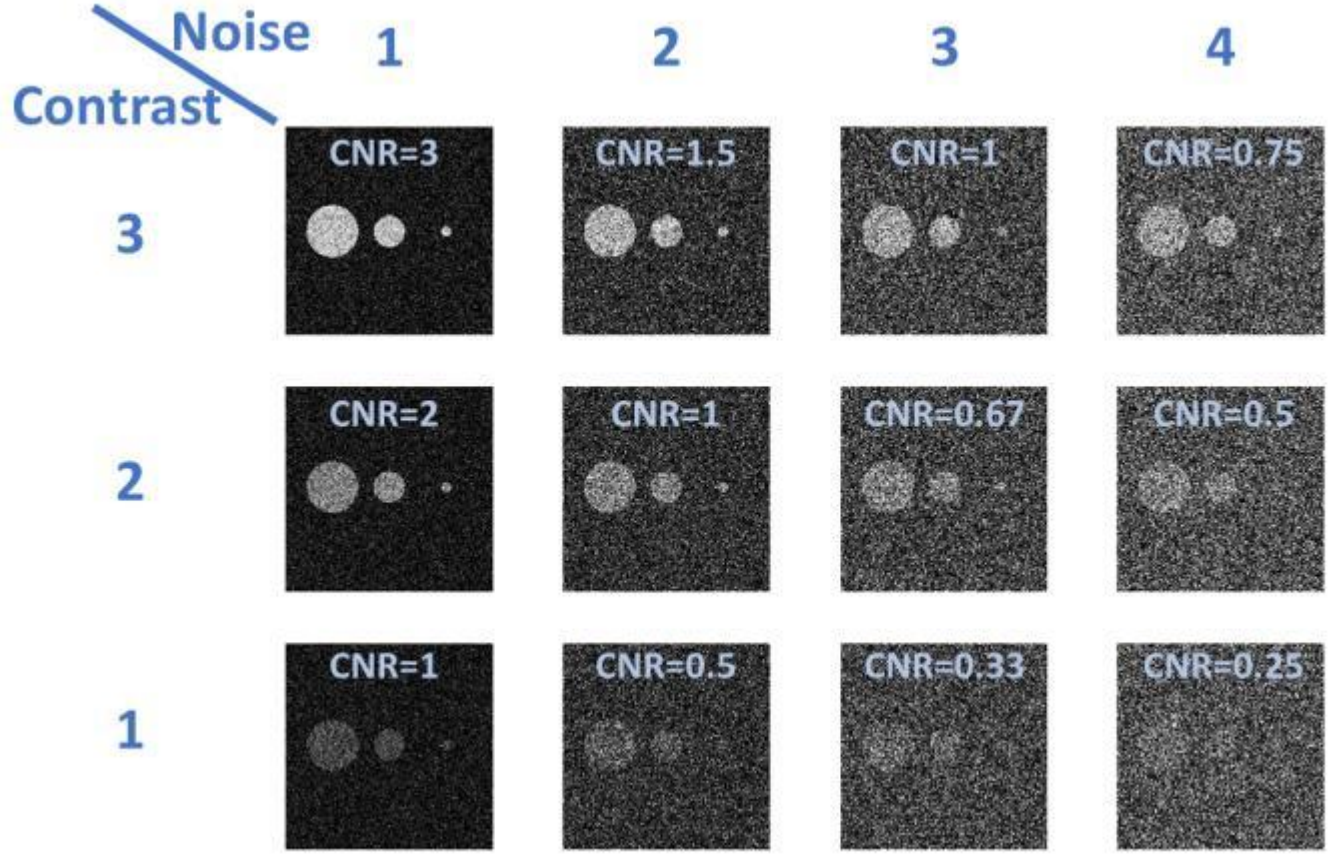


Modulation Transfer Function (MTF)



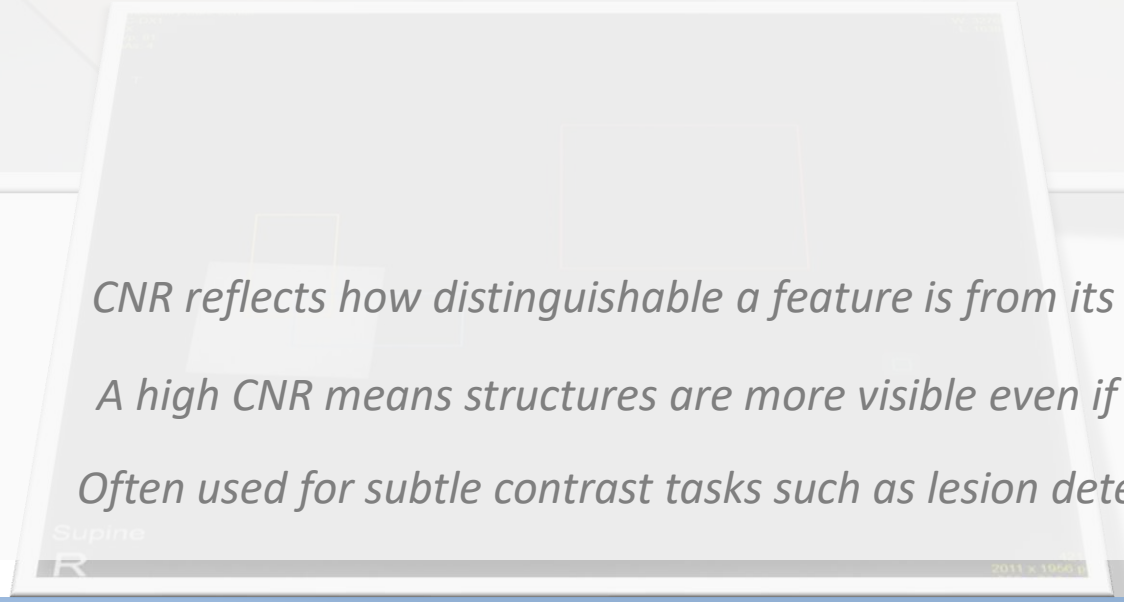
Low Contrast(SDNR)





Contrast-to-Noise Ratio (CNR)

- Measures target visibility over background noise
- Formula: CNR = |Mean target - Mean background| / σ_background
- Higher CNR = better feature visibility



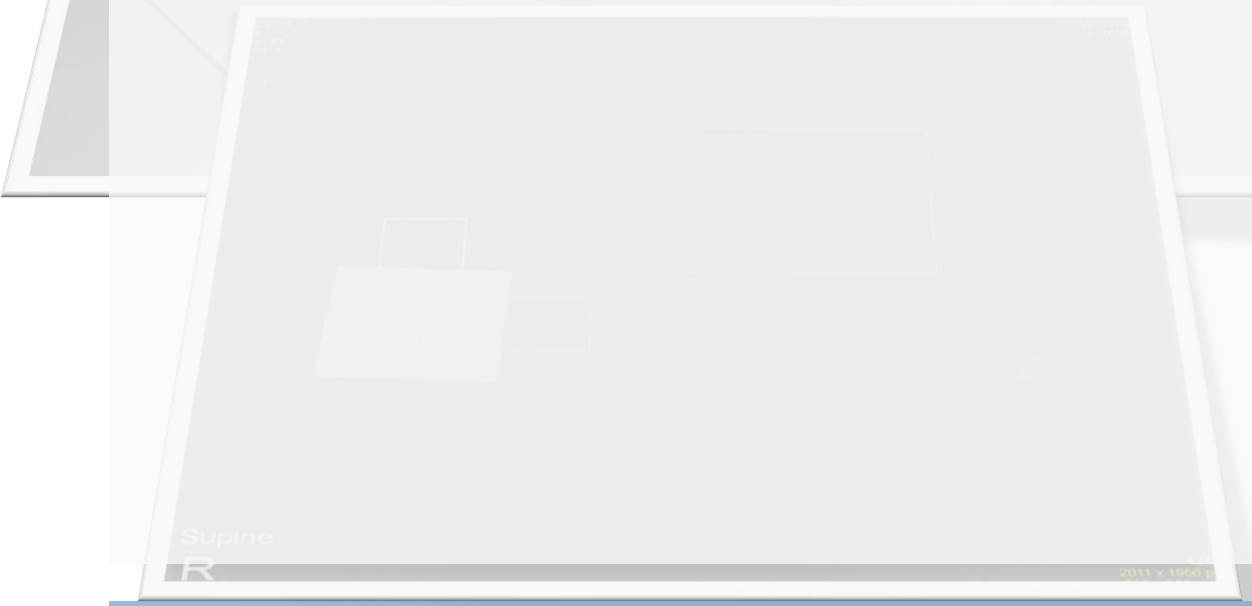
CNR reflects how distinguishable a feature is from its background in the presence of noise.

A high CNR means structures are more visible even if noise exists.

Often used for subtle contrast tasks such as lesion detection.

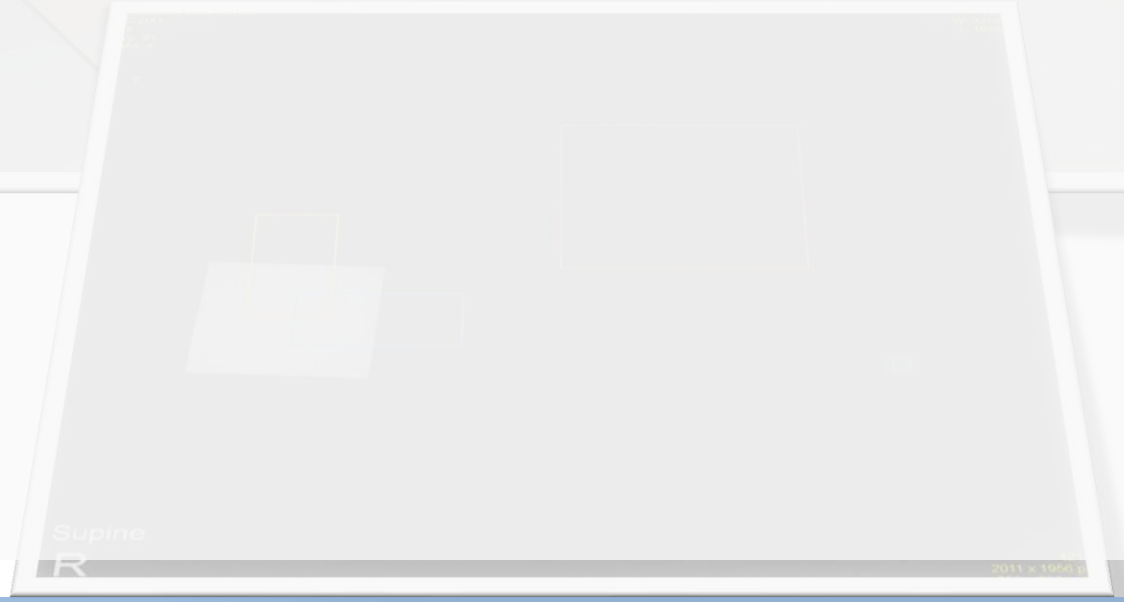
Signal-Difference-to-Noise Ratio (SDNR)

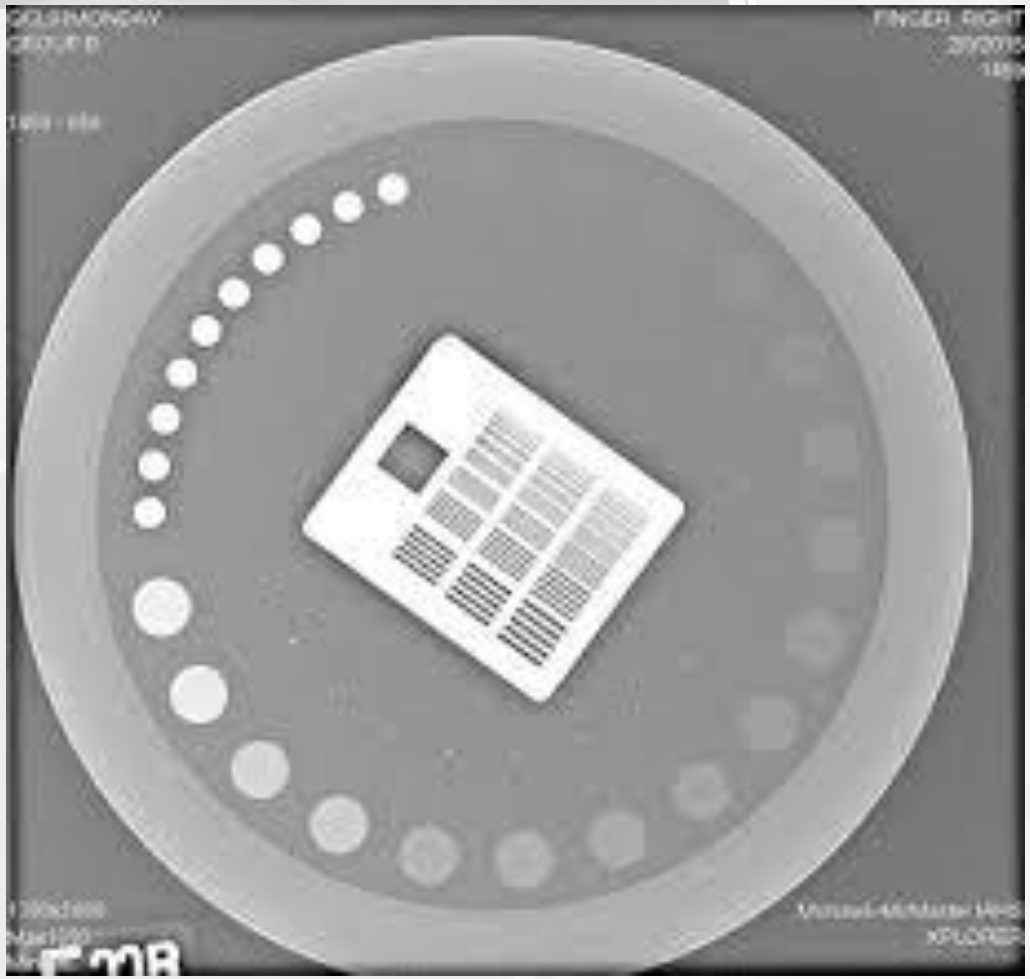
- Focuses on difference between two specific regions
- Formula: SDNR = (Mean_target - Mean_background) / σ_background
- Higher SDNR = better detectability of subtle features



Signal-to-Noise Ratio (SNR)

- Measures strength of signal relative to noise
- Formula: SNR = Mean signal / σ_signal
- Higher SNR = clearer images

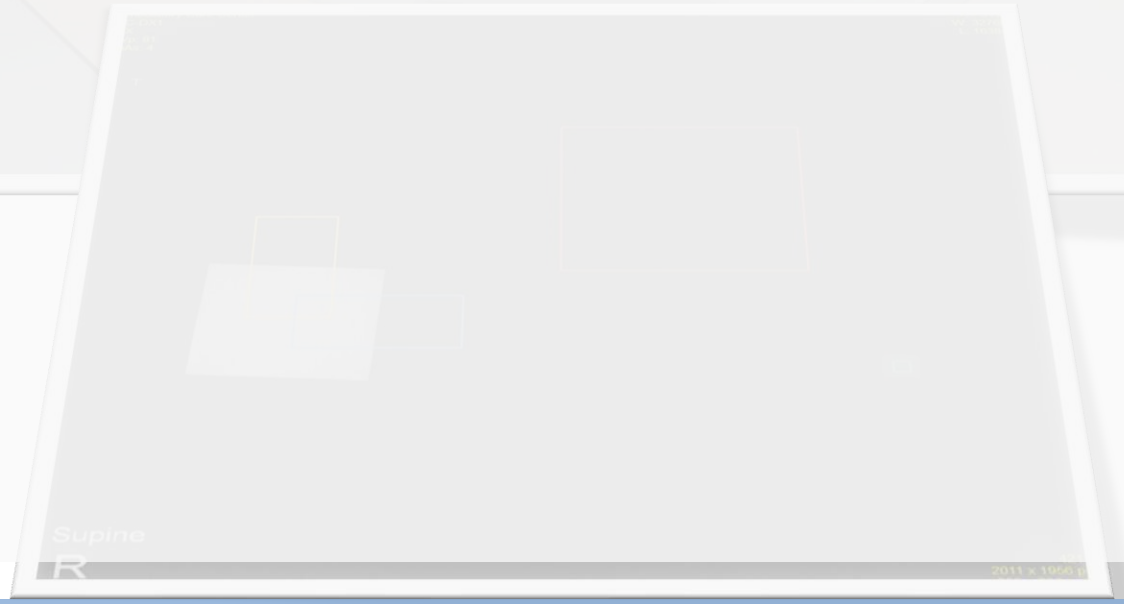




Noise

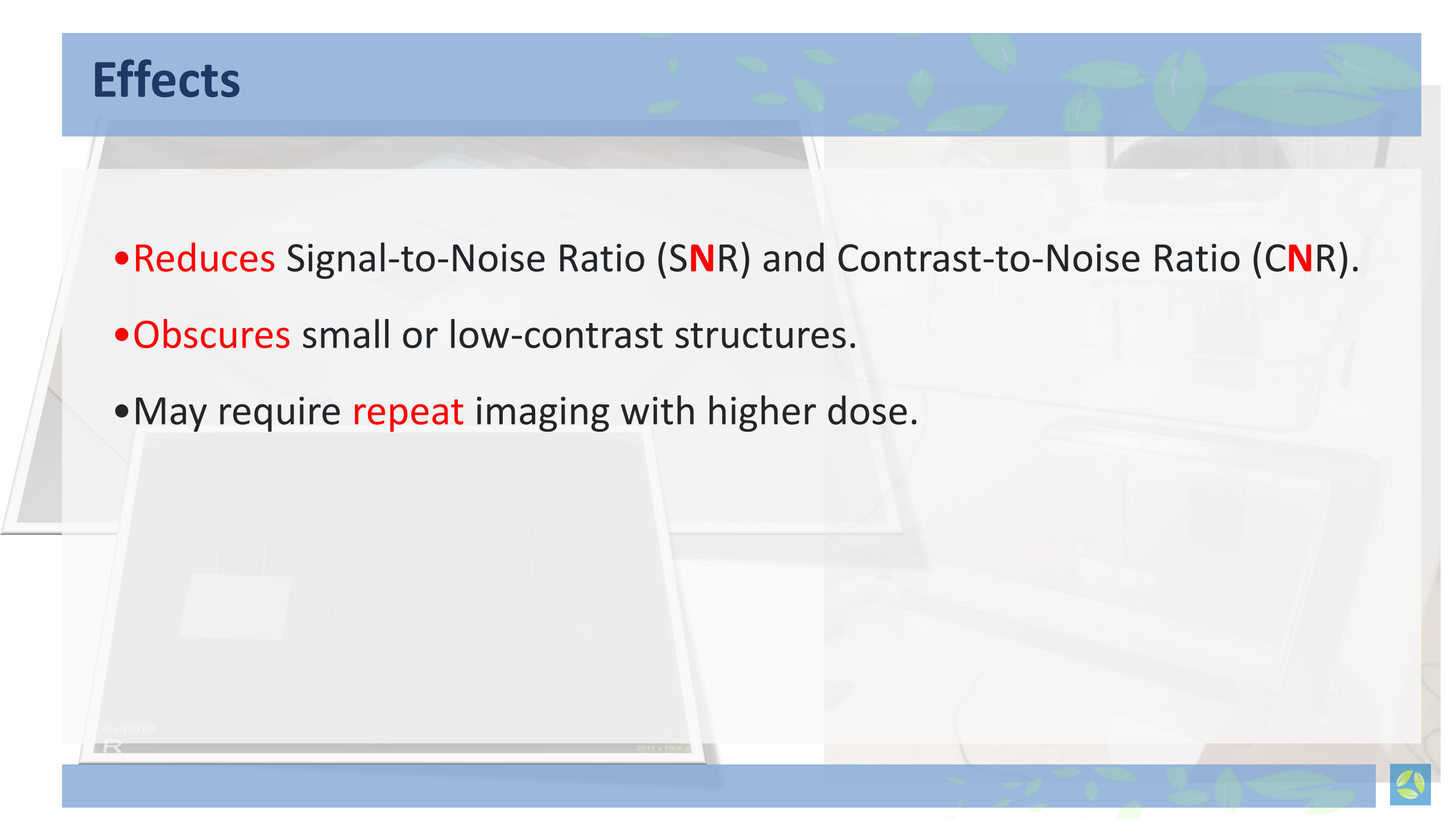
Noise

- Noise refers to **random fluctuations** in pixel values or signal intensity in the image that do not represent actual anatomical details, reducing image quality and making fine details harder to detect.



Effects

- Reduces Signal-to-Noise Ratio (SNR) and Contrast-to-Noise Ratio (CNR).
- Obscures small or low-contrast structures.
- May require repeat imaging with higher dose.



Main sources of noise:

- **Quantum noise:** From the statistical nature of photon emission and absorption; most significant, especially at low dose.
- **Electronic noise:** From detector electronics and readout circuits.
- **Anatomical/structural noise:** From natural tissue patterns (e.g., dense breast tissue).
- **Processing noise:** From digital image processing or reconstruction algorithms.

Reduction strategies:

- Increase photon number (mAs)
- Use noise reduction filters or advanced processing
- Optimize protocol parameters (kVp, mAs, grid).
- Maintain equipment performance through regular **QC**.

In short: Noise is an **unwanted random image component** that carries no patient information. Managing it is essential to balance **image quality** and **radiation dose**, especially in mammography where very fine detail is critical.

NPS: Noise power Spectrum

Rad Take-home Point: Noise power spectrum measures noise variations as a function of spatial frequency.

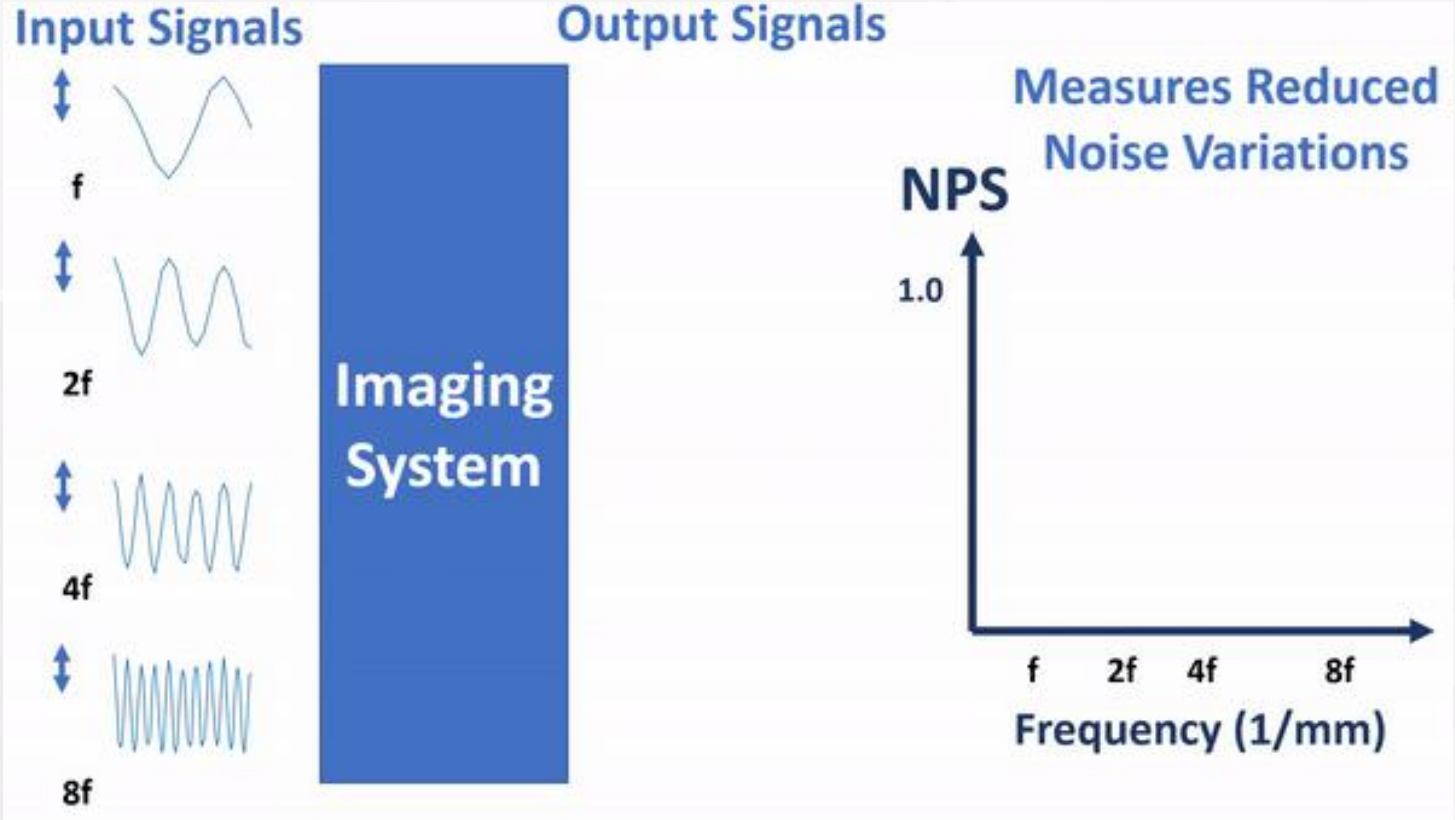
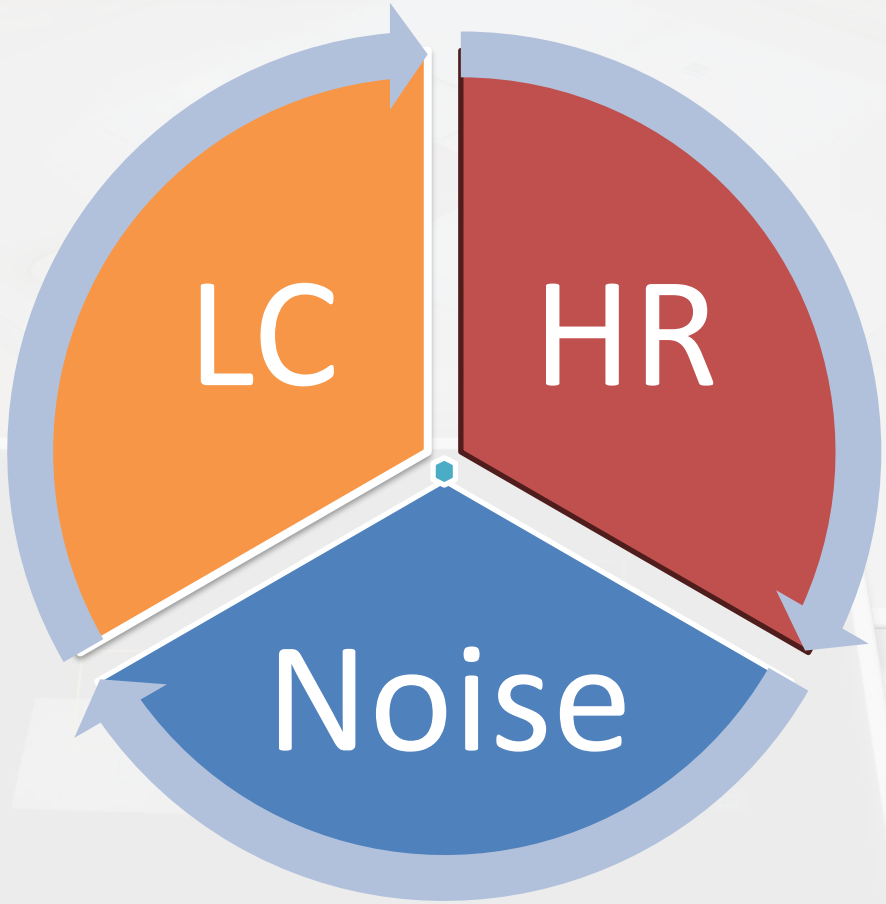


Image Quality metrics

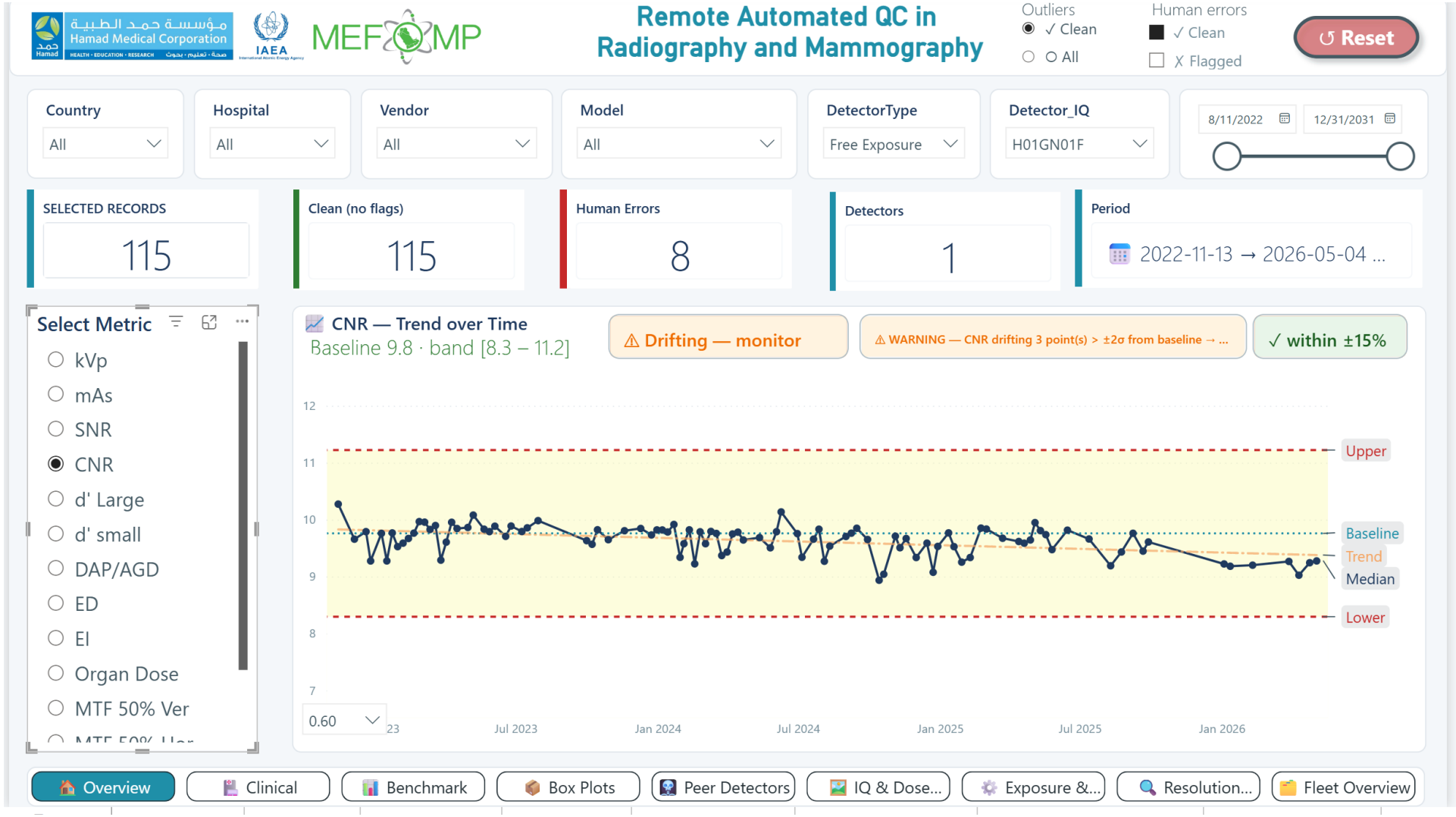


Detectability
d’

Detectability Index (d’)

- Single metric combining **resolution**, **noise**, and **contrast**
- Formula: $d' = \mathrm{sqrt}(\int ((S(f) \times MTF(f))^2 / NPS(f))\, df)$
- Higher d’ = higher detection probability
- Example: Used in phantom studies to predict tumor detectability in low-dose CT
- Example: Higher d’ in mammography improves microcalcification detection

Page-1(Overview)



Remote Automated QC in Radiography and Mammography

Outliers: ✓ Clean / All

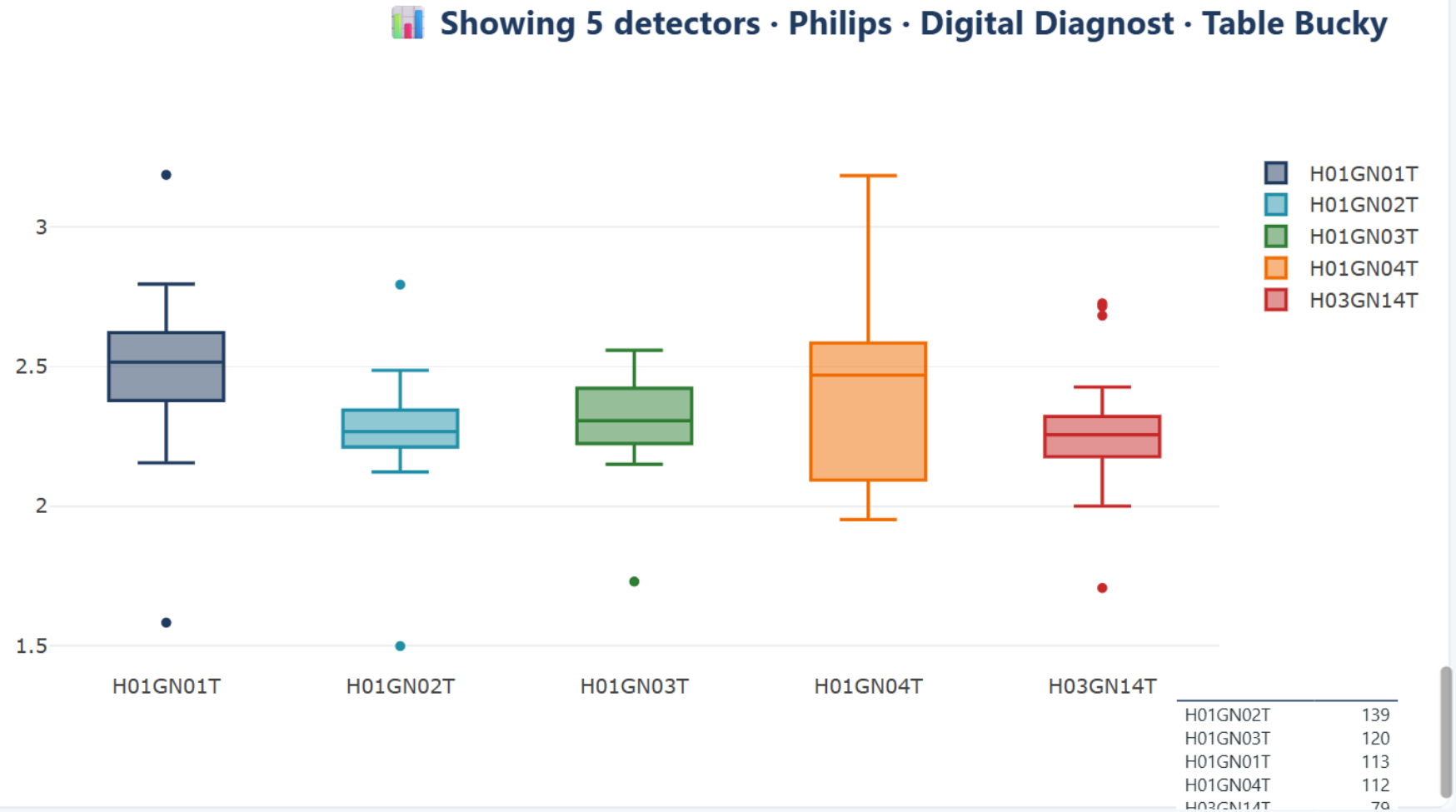
Human errors: ✓ Clean / X Flagged

Reset

Country	Hospital	Vendor	Model	DetectorType	Detector_IQ	
All	All	Philips	Digital Diagnost	Table Bucky	Multiple selectio...	1/1/2022 – 11/4/2030

Metric_Selection

- CNR
- Cumulative KAP
- d' Large
- d' small
- (•) DAP/AGD
- ED
- EI
- kVp
- mAs
- MTF 10% Hor
- MTF 10% Ver
- MTF 20% Hor
- MTF 20% Ver
- MTF 50% Hor
- MTF 50% Ver



Overview | Clinical | Benchmark | Box Plots | Peer Detectors | IQ & Dose... | Exposure &... | Resolution... | Fleet Overview

Remote Automated QC in Radiography and Mammography

Outliers: ✓ Clean / ○ All

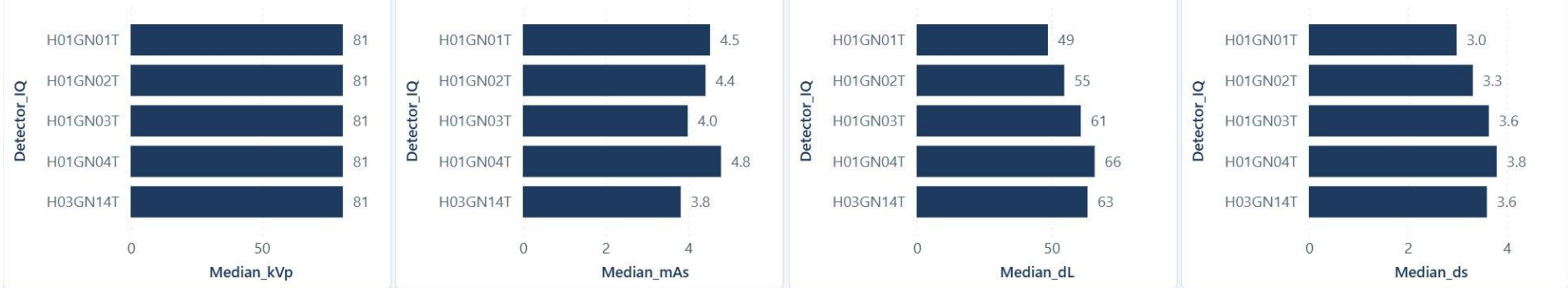
Human errors: ■ ✓ Clean / ☐ X Flagged

↺ Reset

Country	Hospital	Vendor	Model	DetectorType	Detector_IQ	
All	All	Philips	Digital Diagnost	Table Bucky	Multiple selectio...	1/1/2022 – 11/4/2030

Showing 5 detectors · Philips · Digital Diagnost · Table Bucky

Detector_IQ	Type	Intent	SID_cm	Protocol	AEC	kVp	mAs	SNR	SdNR	dL	ds	DAP	ED	MTF50v	MTF50h
H01GN01T	Table Bucky	FOR PRESENTATION	110	Abdomen		81	4.5	14.0	7.7	49.2	3.0	2.59	0.50	1.68	1.58
H01GN02T	Table Bucky	FOR PRESENTATION	110	Abdomen		81	4.4	14.0	8.3	55.4	3.3	2.34	0.44	1.72	1.60
H01GN03T	Table Bucky	FOR PRESENTATION	110	Abdomen		81	4.0	13.4	8.2	59.3	3.6	2.52	0.48	1.73	1.66
H01GN04T	Table Bucky	FOR PRESENTATION	110	Abdomen		81	4.8	13.8	8.5	67.6	3.8	2.26	0.41	1.67	1.67
H03GN14T	Table Bucky		110	Abdomen		81	3.8	14.6	8.4	63.7	3.6	2.27	0.43	1.63	1.62



Overview | Clinical | Benchmark | Box Plots | Peer Detectors | IQ & Dose... | Exposure &... | Resolution... | Fleet Overview

Remote Automated QC in Radiography and Mammography

Outliers: ✓ Clean / All
Human errors: ✓ Clean / X Flagged
Reset

Country	Hospital	Vendor	Model	DetectorType	Detector_IQ	Date range
All	All	Philips	Digital Diagnost	Table Bucky	H01GN03T	1/1/2022 – 11/4/2030

SELECTED RECORDS	Clean (no flags)	Human Errors	Detectors	Period
106	120	28	1	2022-11-13 → 2026-05-04 · 3y · 5m · 3w

Select Metric

- kVp
- mAs
- SNR
- CNR
- d' Large
- d' small
- DAP/AGD
- ED
- EI
- Organ Dose
- MTF 50% Ver
- MTF 50% Hor

SNR — Trend over Time

Baseline 13.3 · band [11.3 – 15.3]

Stable
Detector stable — continue routine monitoring.

Overview | Clinical | Benchmark | Box Plots | Peer Detectors | IQ & Dose... | Exposure &... | Resolution... | Fleet Overview

Remote Automated QC in Radiography and Mammography

Outliers: ✓ Clean / All

Human errors: ✓ Clean / Flagged

Reset

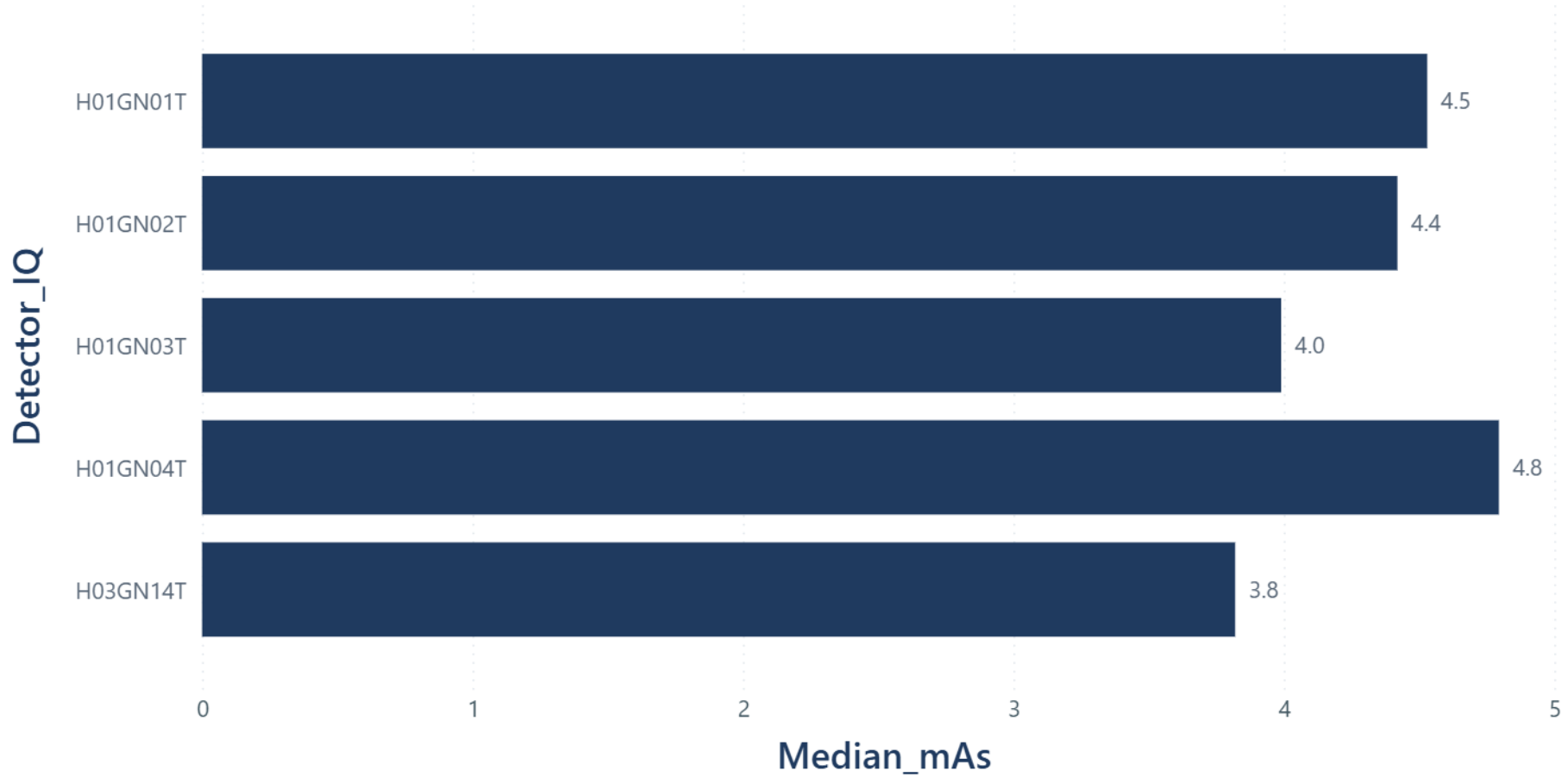
Country: All | Hospital: All | Vendor: Philips | Model: Digital Diagnost | DetectorType: Table Bucky | Detector_IQ: Multiple selectio... | 1/1/2022 – 11/4/2030

Metric_Median

- Median_DAP
- Median_dL
- Median_ds
- Median_ED
- Median_EI
- Median_kVp
- Median_MTF50h
- **Median_mAs**
- Median_MTF50v
- Median_OrganDose
- Median_SDNR
- Median_SID
- Median_SNR

SID

Showing 5 detectors · Philips · Digital Diagnost · Table Bucky



Overview | Clinical | Benchmark | Box Plots | Peer Detectors | IQ & Dose... | Exposure &... | Resolution... | Fleet Overview

Remote Automated QC in Radiography and Mammography

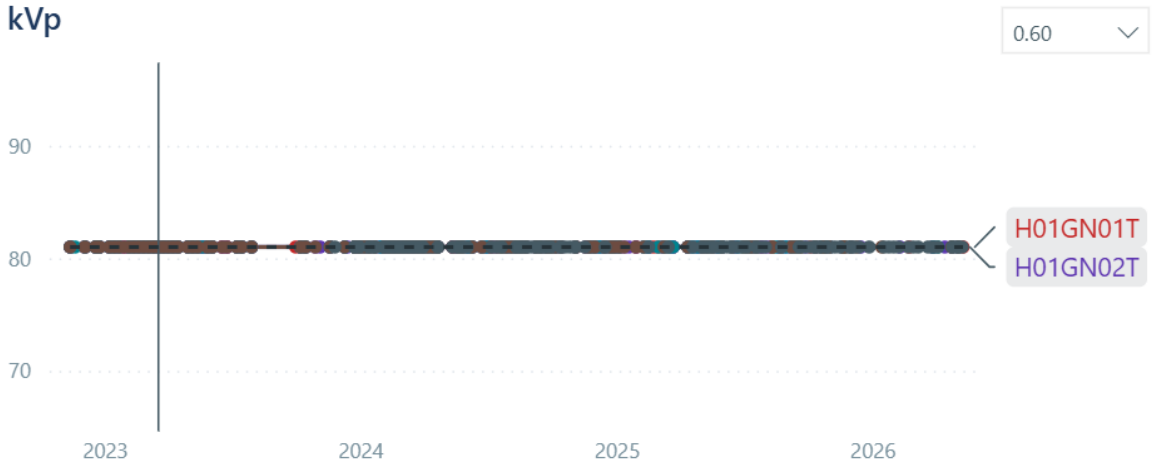
Outliers: ✓ Clean / All

Human errors: ✓ Clean / X Flagged

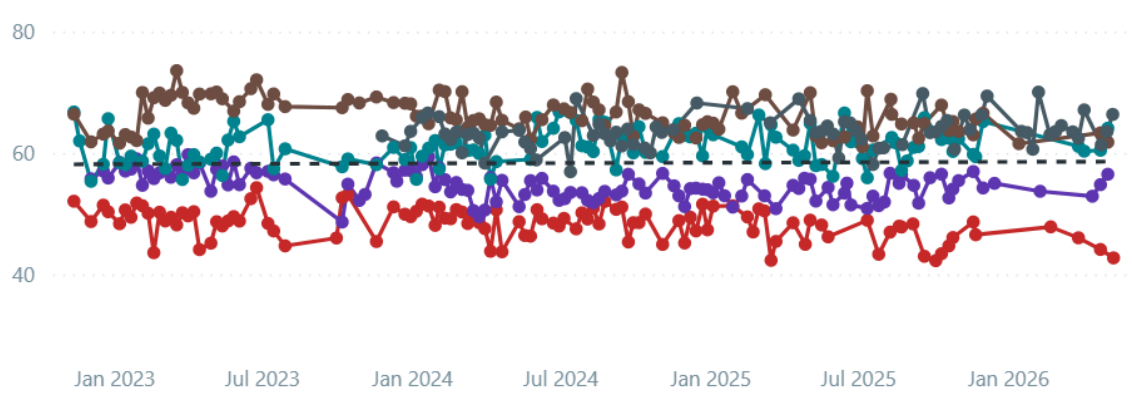
Reset

Country: All | Hospital: All | Vendor: Philips | Model: Digital Diagnost | DetectorType: Table Bucky | Detector_IQ: Multiple sele... | 1/1/2022 – 11/4/2030

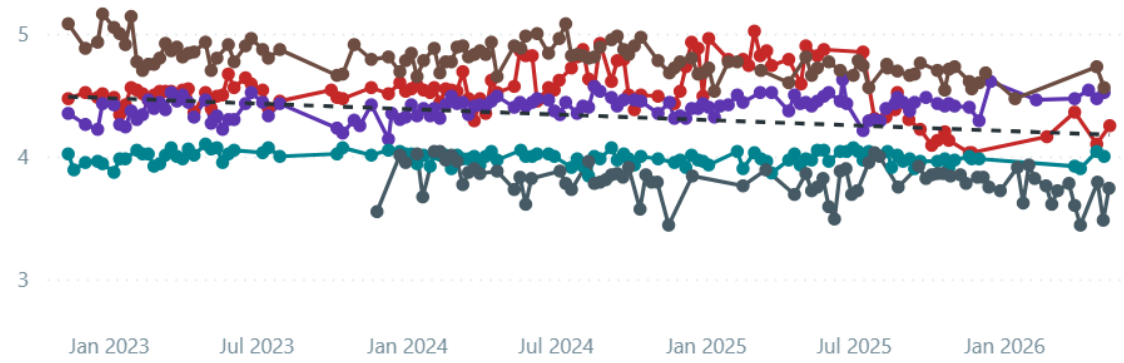
kVp



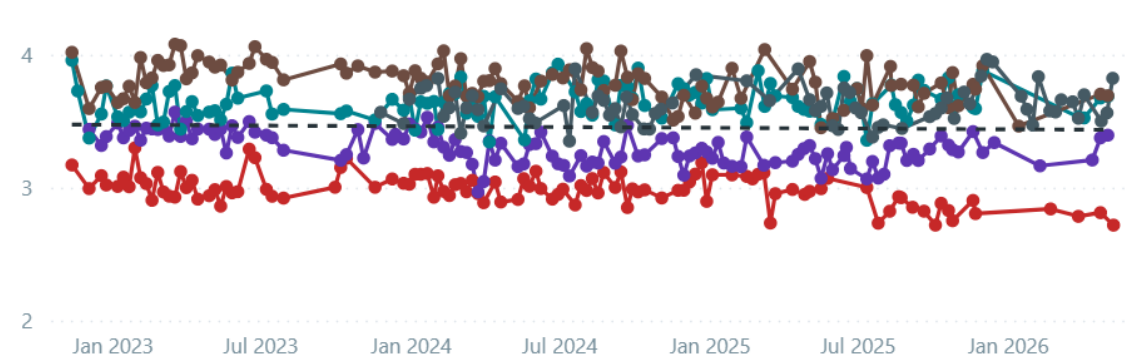
d' Large



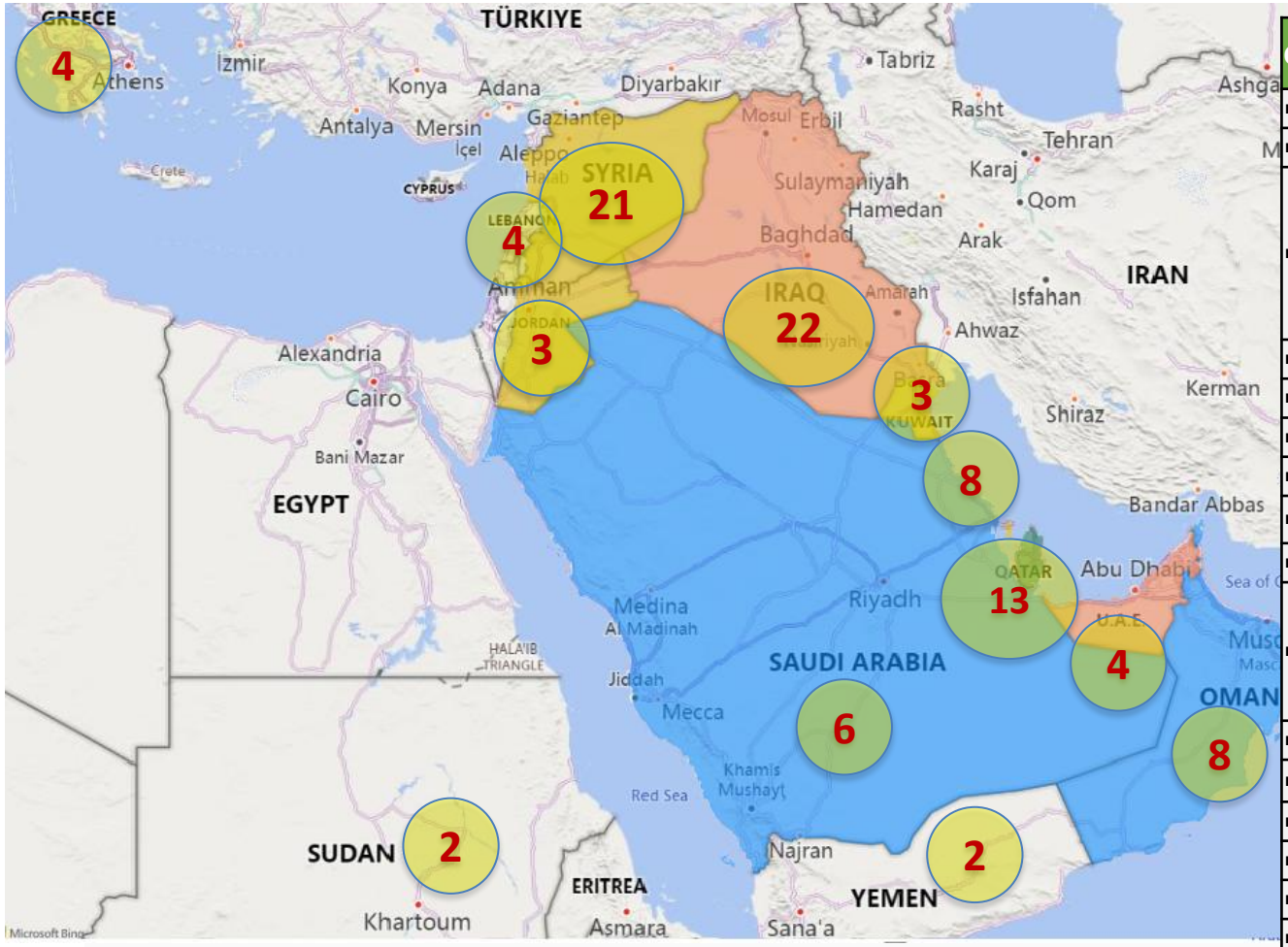
mAs



d' small

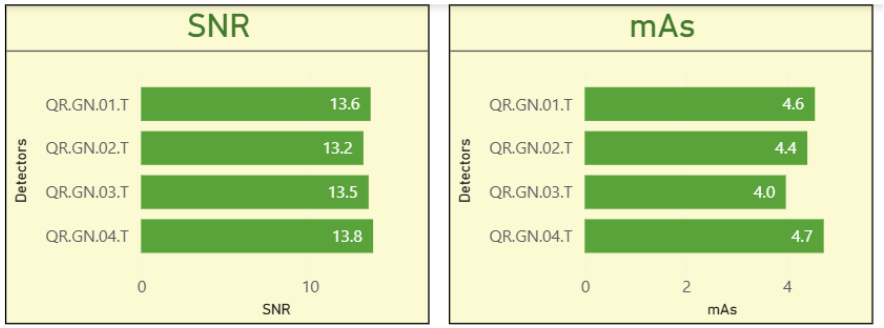


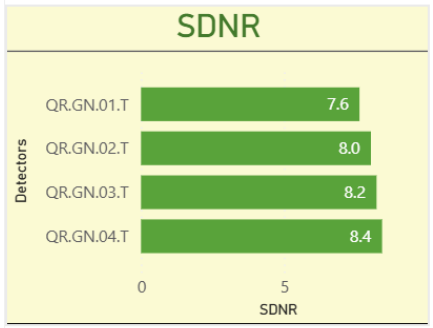
HMC in collaboration with MEFOMP distributed these Phantoms to most counties in the region

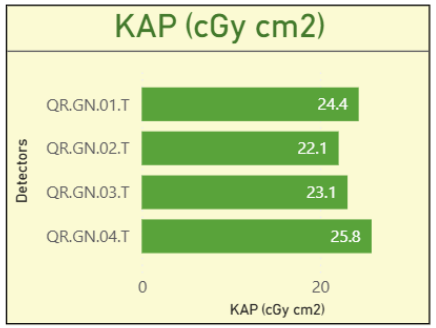


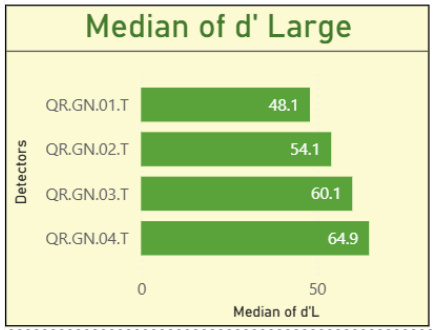
Country	Radiography	Mammography	Phantoms	comments
▪ Qatar	8	5	13	
▪ Bahrain	4	4	8	
▪ Iraq	11	11	22	2026 - National workshop organized in collaboration with HMC and MEFOMP Postponed due to the regional crises
▪ Jordan	2	1	3	
▪ Kuwait	2	1	3	
▪ Lebanon	2	2	4	
▪ Oman	5	3	8	
▪ Saudi Arabia	3	3	6	
▪ Sudan	1	1	2	
▪ Syria	11	10	21	2026 - National workshop organized in collaboration with HMC and MEFOMP May 19-21, 2026
▪ UAE	2	2	4	
▪ Yemen	1	1	2	
▪ Greece	2	2	4	
▪ UK	1	1	2	
▪ Pakistan	1	1	2	
▪ Fiji	1	1	2	
▪ Australia	1	1	2	
▪ Total	**58**	**50**	**108**	

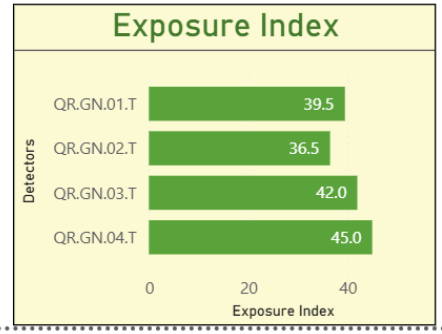
Monitoring the performance of a detector

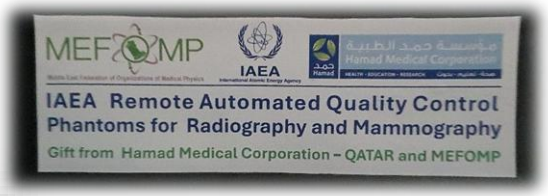


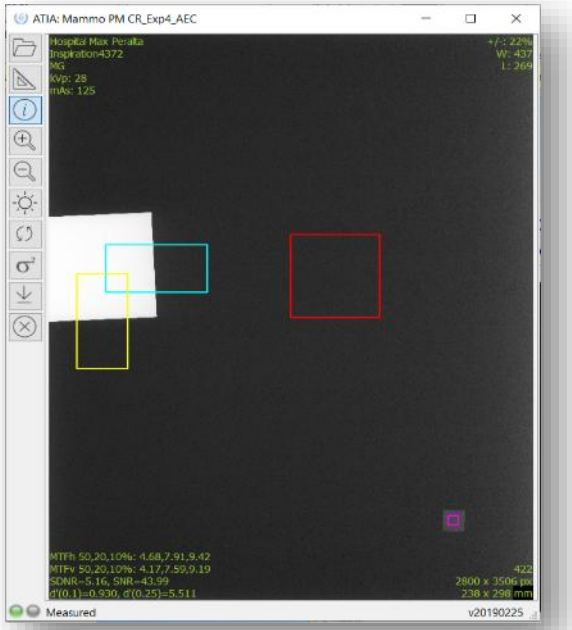












Comparing the overall performance of a detector with detectors from the same company and model

Thank you for your attention,