Display Quality Assurance: Considerations When Establishing a Display QA Program

Mike Silosky, M.S.

8/3/2017

Objectives and Outline

Why, Who, What, When, Where?

- Discuss the resources that may be needed for a display QA program and how these resources may be utilized

How do flat panel displays fail?

- Review some common modes of failure for LCDs and discuss testing strategies

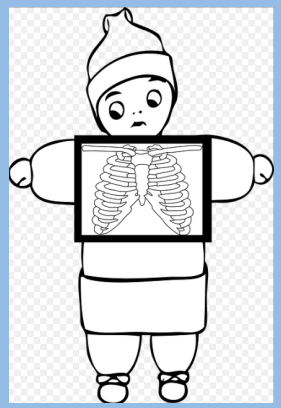
What about existing guidelines and requirements?

- Compare and contrast the TG-270 recommendations with requirements provided by accreditation organizations (ACR and TJC)

Why perform display QA?

- Display performance has a direct impact on the information that physicians have available when making a diagnosis and may effect decision making
- Ensure consistent display of medical images from acquisition to interpretation (and beyond)
- Accrediting bodies have implemented requirements regarding quality assurance testing of displays used in medical imaging (TJC, ACR)

Who performs display QA?



Imaging Technologists

Physicists/Assistants

Biomedical Engineering

PACS Personnel

What to test and when

Documented QA Test	Display Type			
	Diagnostic	Modality	CSD	EHRD
Qualitative Luminance Response	Quarterly	Quarterly	Annually	Annually
Qualitative Ambient Luminance/Illuminance	Quarterly	Annually	Annually	Annually
Qualitative Uniformity	Quarterly	Annually	Annually	Annually
Qualitative Spatial Resolution	Quarterly	Annually	Annually	Annually
Quantitative Min/Max Luminance	Annually	Annually	Annually	Acceptance
Quantitative Luminance Response	Annually	Annually	Acceptance	Acceptance
Quantitative Color Assessment	Annually	Annually	Acceptance	Acceptance
Quantitative Ambient Luminance/Illuminance	Annually	Acceptance	Acceptance	Acceptance
Quantitative Uniformity	Acceptance	Acceptance	Acceptance	Evaluation
Qualitative Noise	Evaluation	Evaluation	Evaluation	Evaluation
Qualitative Temporal Resolution	Evaluation	Evaluation	Evaluation	Evaluation
Diffuse Reflection Coefficient (R_d)	Evaluation	Evaluation	Evaluation	Evaluation

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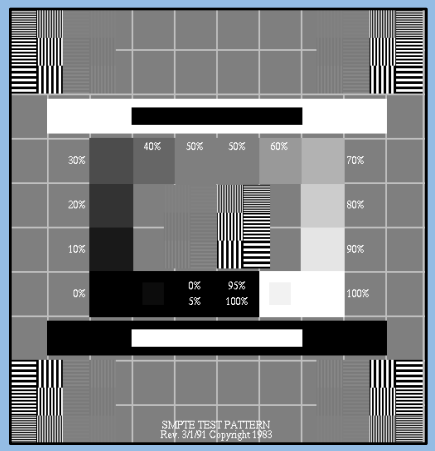
Where?

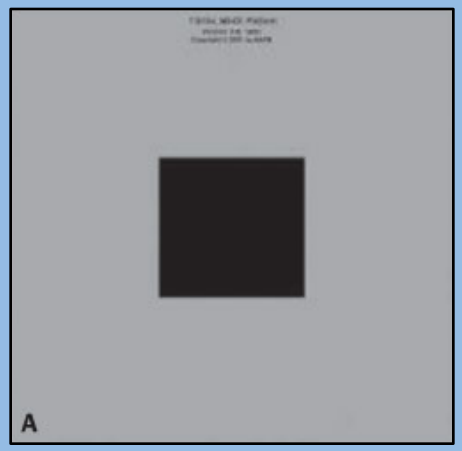
- Reading Rooms
- Clinical Areas
- Personal Offices
- Storage Rooms/ isolated areas
- Houses???

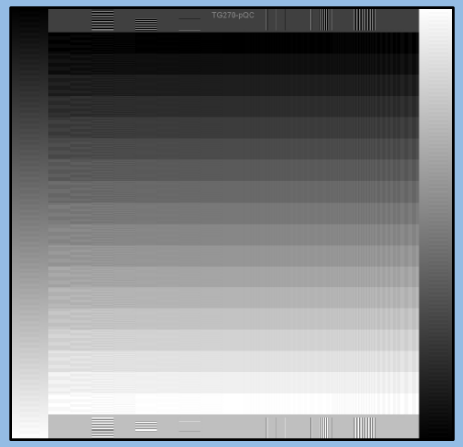
Tools: Photometers/Colorimeters

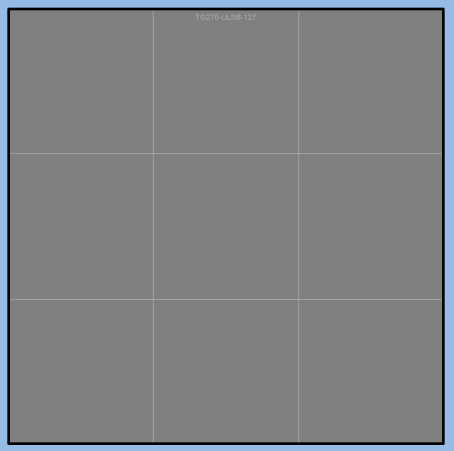
https://www.aapm.org/pubs/reports/OR_03.pdf

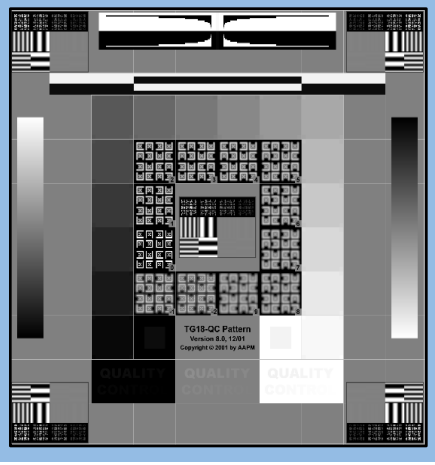
Tools: Test Patterns

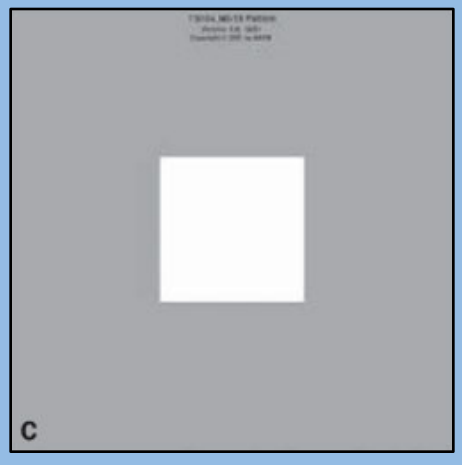


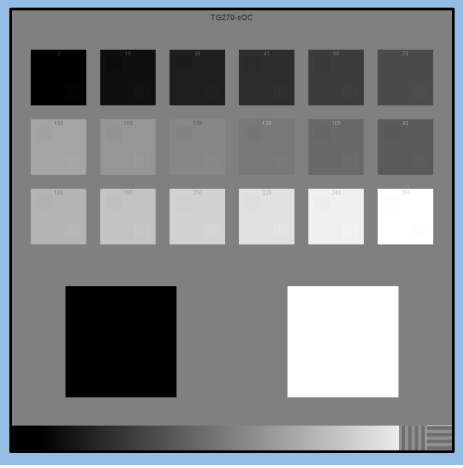


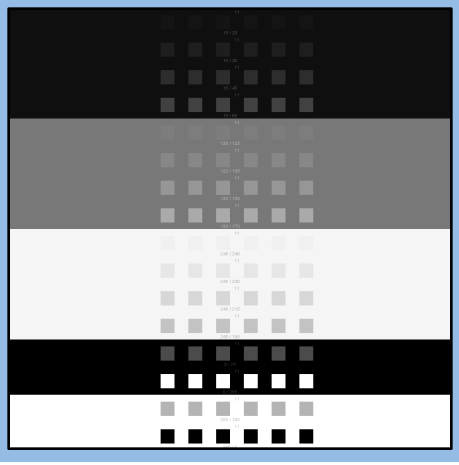












Tools: Vendor/3rd Party Software

- What Software are you going to use?
- What measurements can be made?
- How reliable is this software?
- Who is going to review the results?
- How is QA going to be performed on vendor provided tools?

Common Modes of Failure

Example: Imaginary Hospital

- 200 Diagnostic displays
- 50-60 Modality Workstations
- 10 Clinical Specialist Workstations
- Innumerable Electronic Health Record Workstations

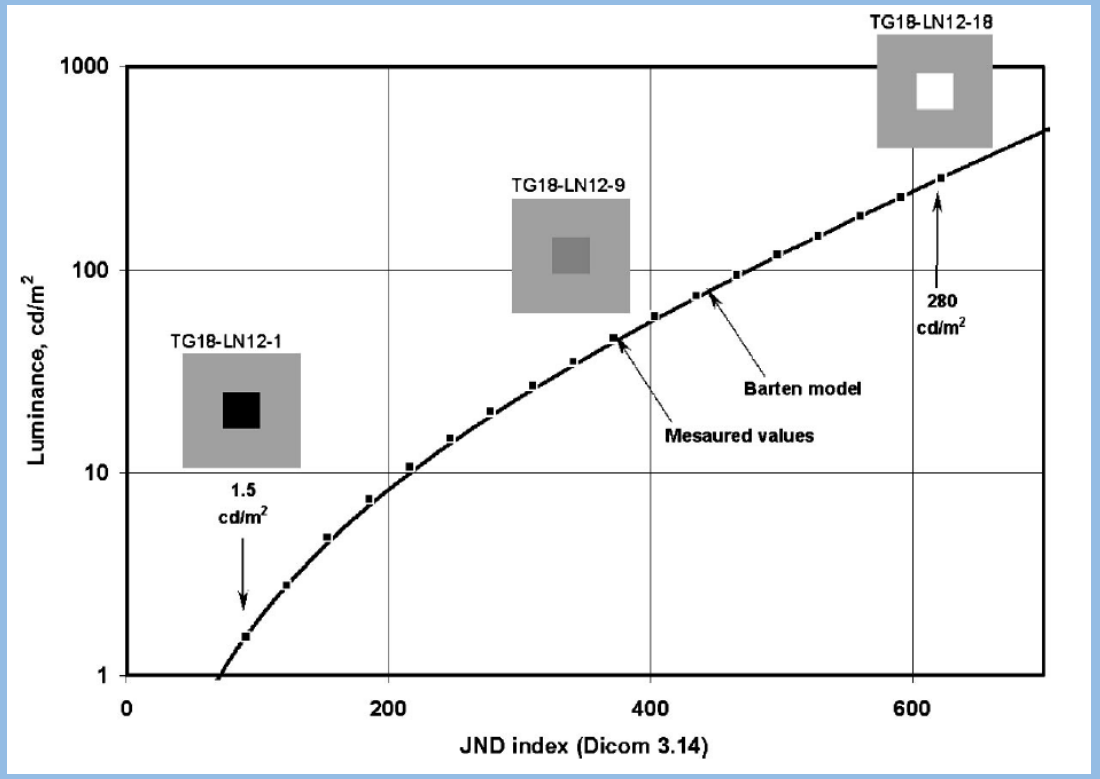
Goals:

1. **Maximize the diagnostic value of acquired images**

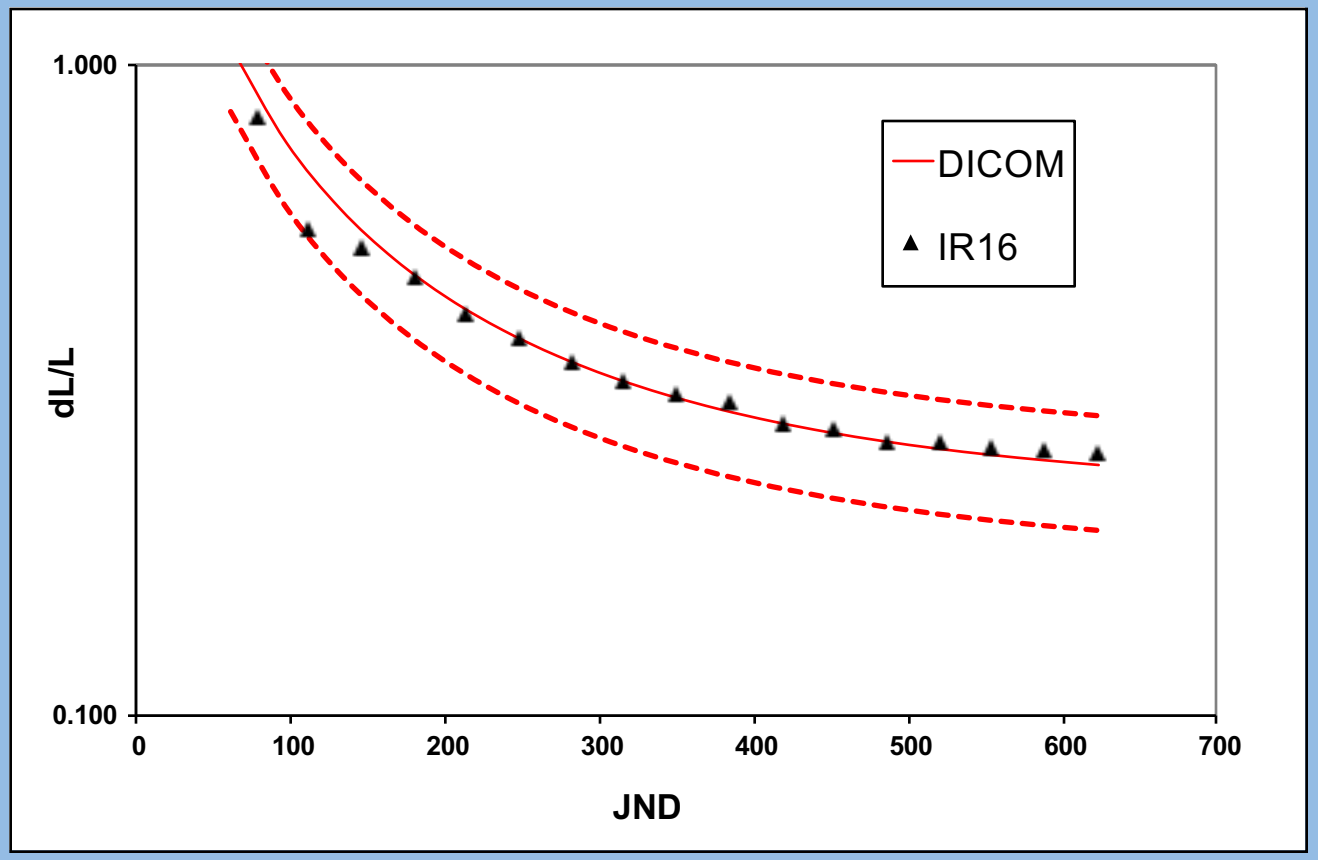
2. **Ensure consistent presentation of medical images from acquisition to interpretation.**

GSDF Compliance

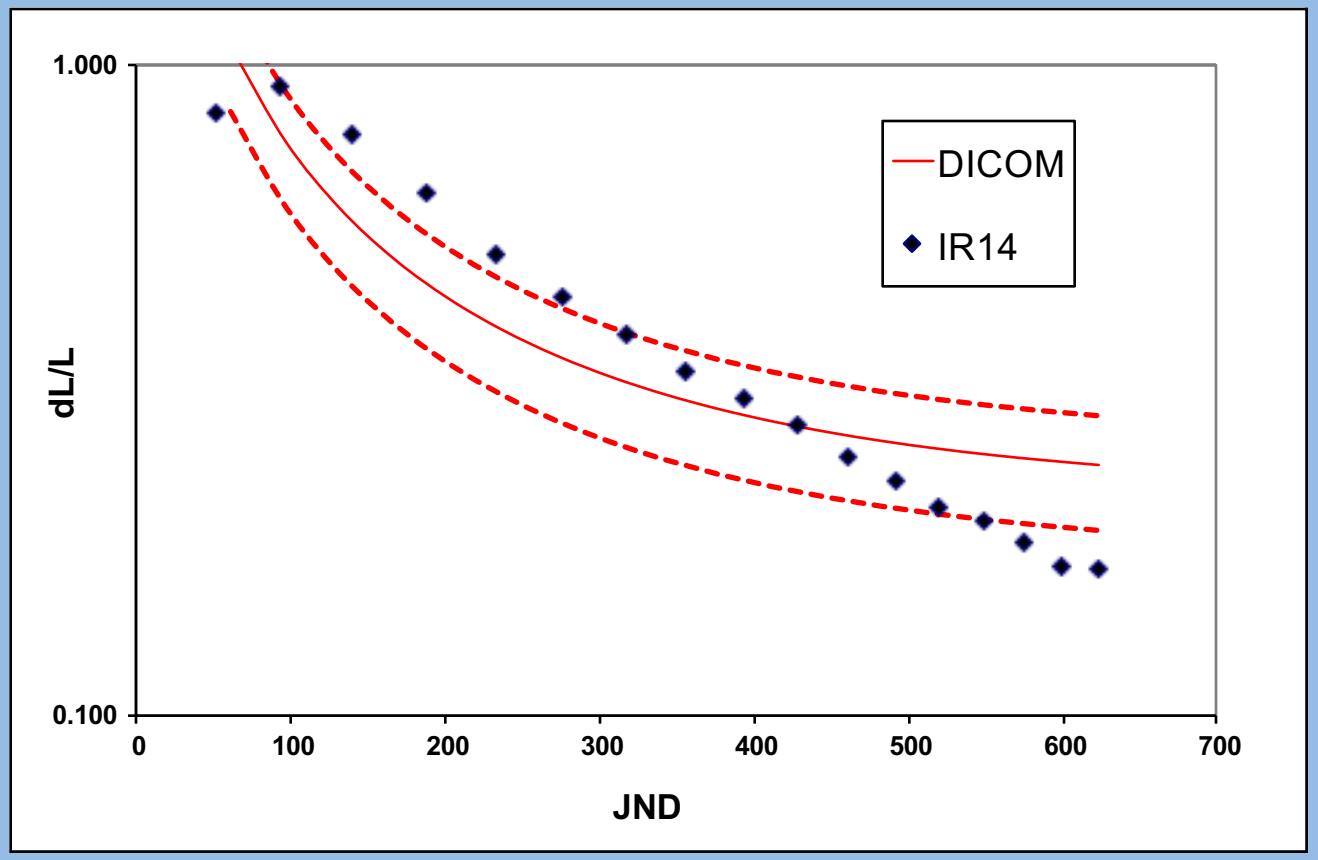
- Primary displays are typically compliant
- Some modality displays are compliant
- Most other devices require calibration to become GSDF compliant



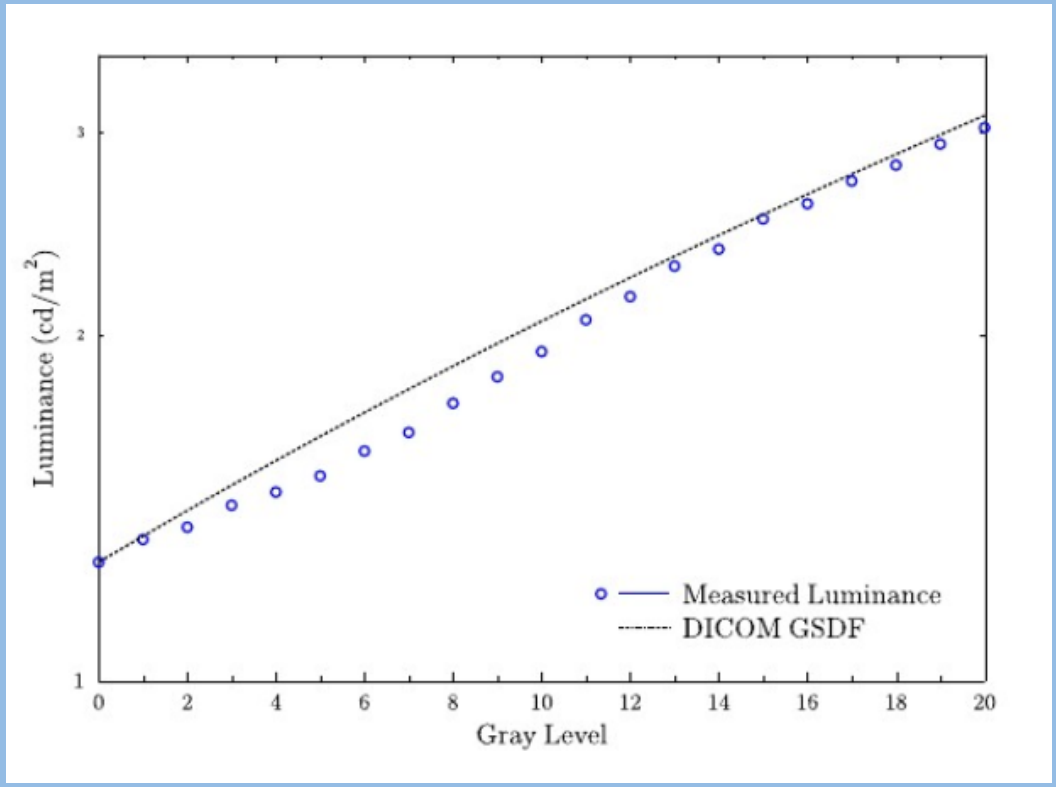
Example 1



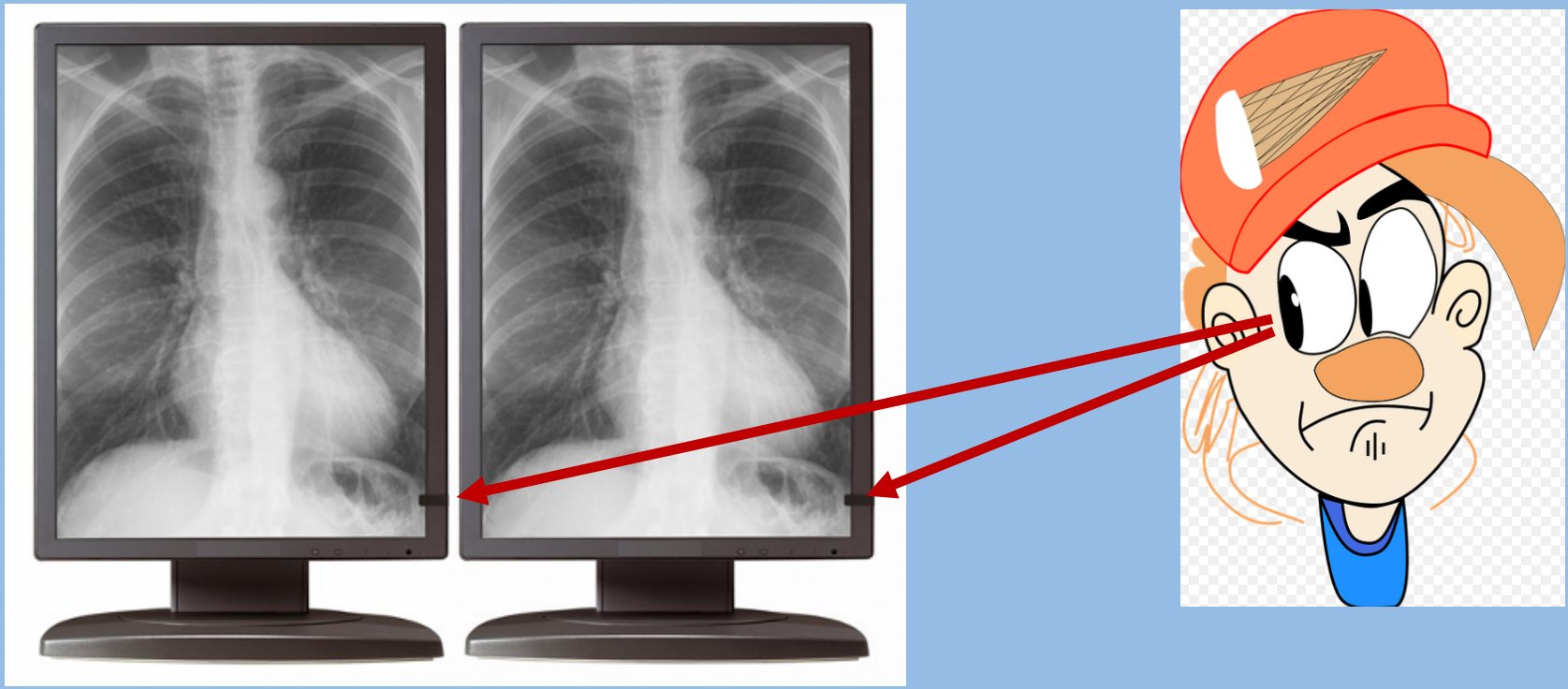
Example 2



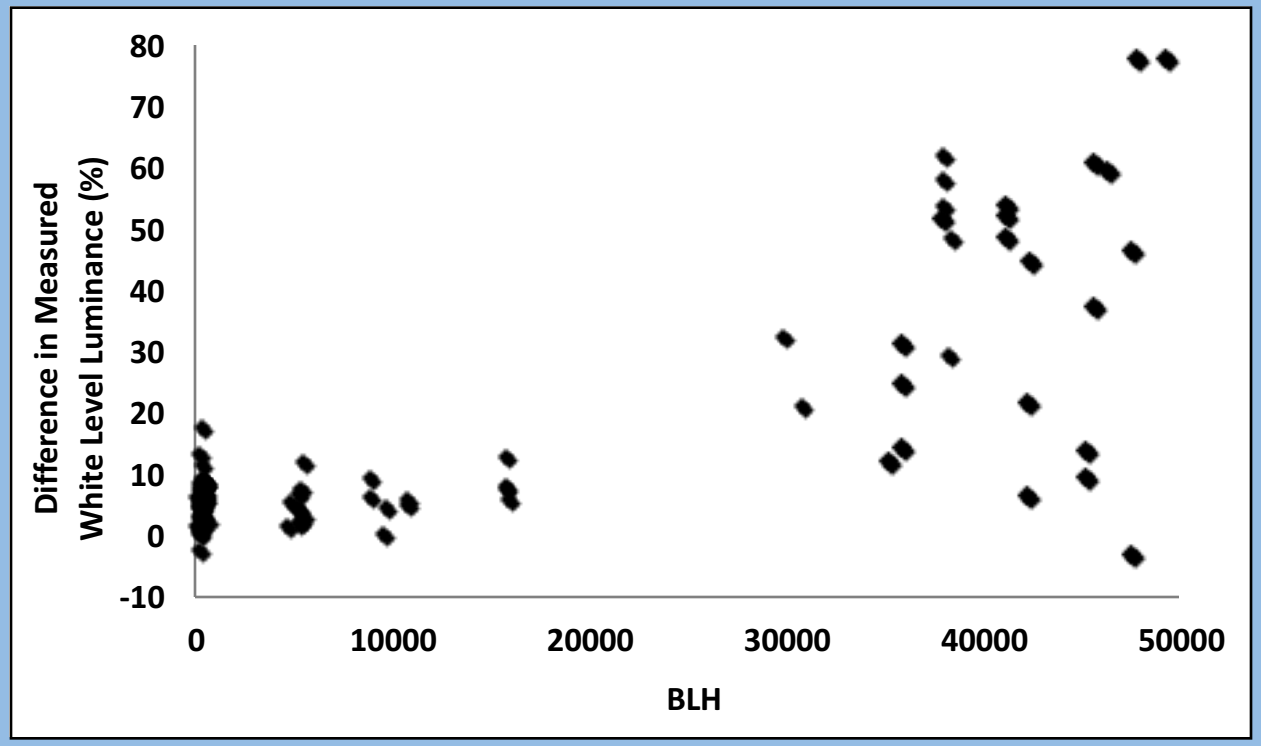
Example 3


Luminance (cd/m^2)
Gray Level
Measured Luminance
DICOM GSDF
1
2
3
0
2
4
6
8
10
12
14
16
18
20

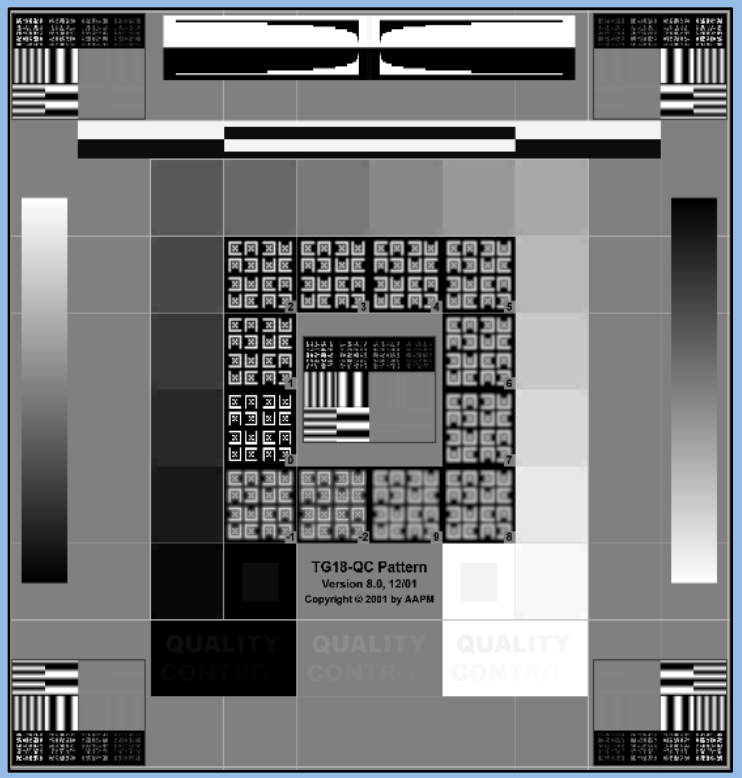
Are you relying on a built-in photometer?

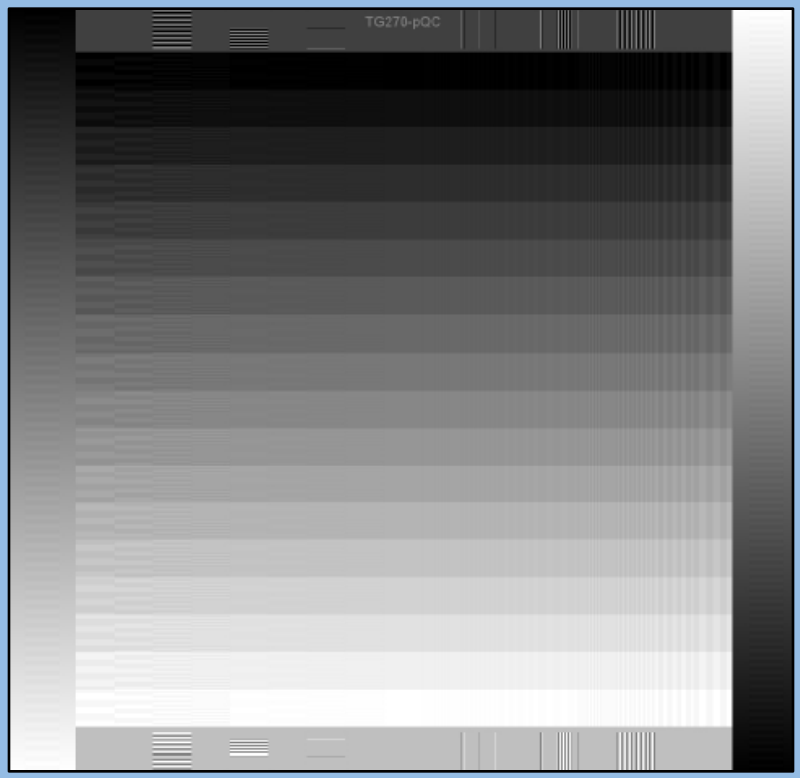


As displays age, built-in photometers drift



Contrast Perception





Ambient Luminance and Luminance Ratio

$$R_L = \frac{L'max}{L'min}$$

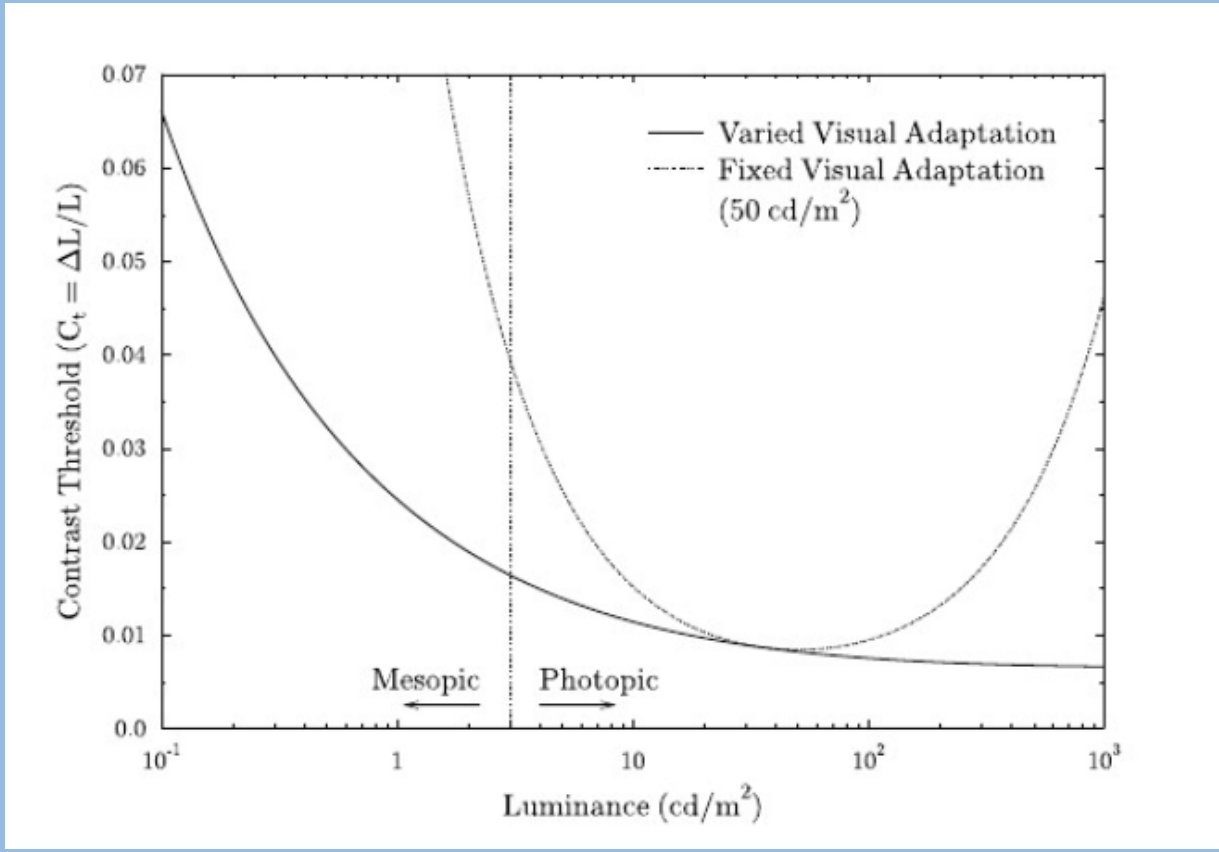
$$= \frac{Lmax + Lamb}{Lmin + Lamb}$$

TABLE II. Estimated Reflection Coefficient Comparison

	Case 1	Case 2
Ambient Illuminance (E)	40 lux	40 lux
Reflection Coefficient (R_d)	0.005 cd/m^2/lux	0.010 cd/m^2/lux
Ambient Luminance (L_{amb})	0.2 cd/m^2	0.4 cd/m^2
Minimum Luminance (L'_{min})	1.0 cd/m^2	2.0 cd/m^2
Maximum Luminance (L'_{max})	350 cd/m^2	700 cd/m^2

R_L = 350

Maintaining the same Luminance Ratio and Luminance response function is essential for the consistent presentation of medical images

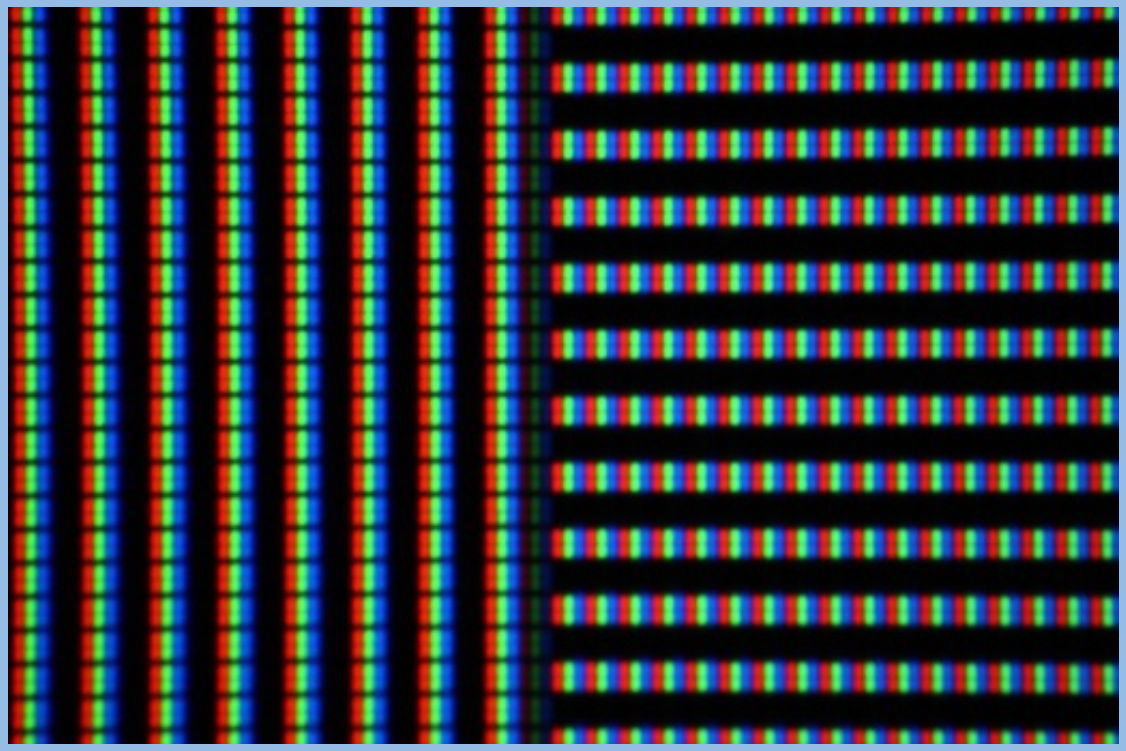


Perceived contrast is highly dependent on the average luminance of the scene

Uniformity

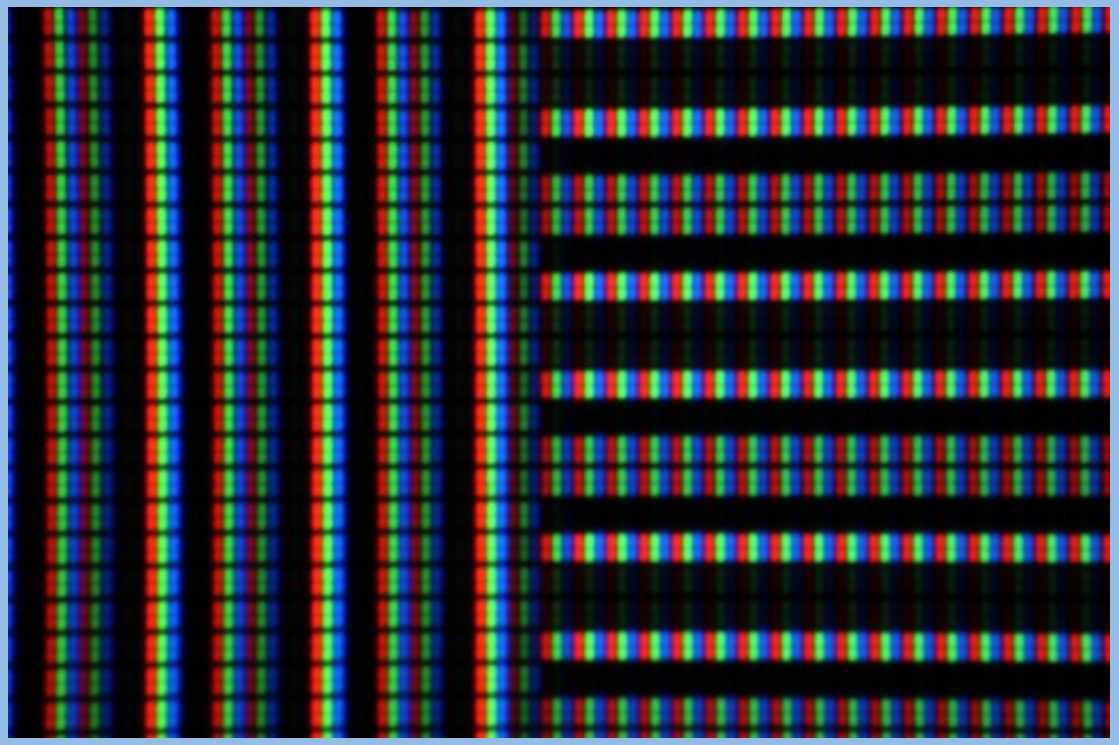
- Quantitative
  - -Acceptance Only
- Qualitative
  - -Routinely

Spatial Resolution



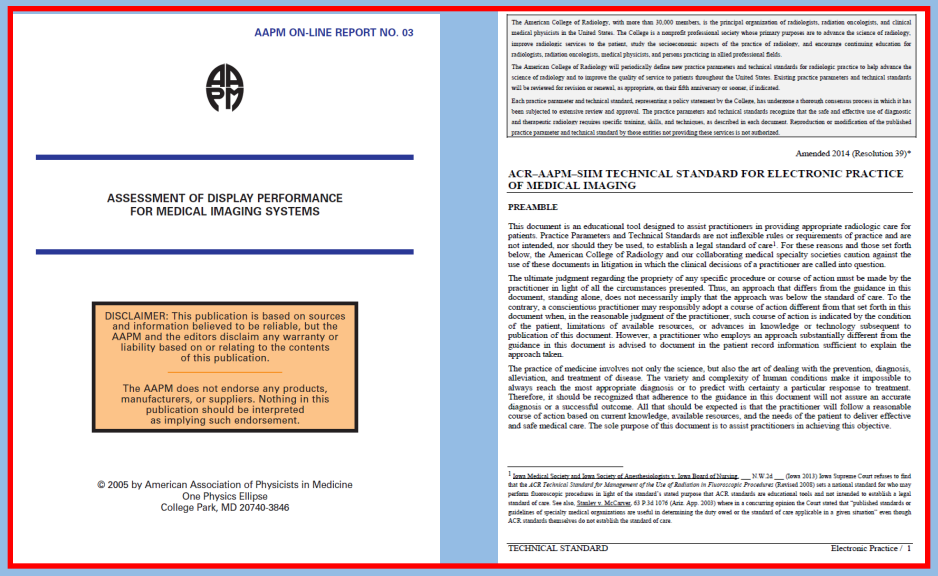
Graphics driver set to the native resolution of the display

Spatial Resolution



Graphics driver set to non-native resolution of the display

What about existing guidance/requirements?



AAPM ON-LINE REPORT NO. 03

ASSESSMENT OF DISPLAY PERFORMANCE
FOR MEDICAL IMAGING SYSTEMS

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Each practice parameter and technical standard, representing a policy statement by the College, has undergone a thorough consensus process in which it has been subjected to extensive review and approval. The practice parameters and technical standards recognize that the safe and effective use of diagnostic and therapeutic radiology requires specific training, skills, and techniques, as described in each document. Reproduction or modification of the published practice parameter and technical standard by those entities not providing these services is not authorized.

Amended 2014 (Resolution 39)*

ACR–AAPM–SIIM TECHNICAL STANDARD FOR ELECTRONIC PRACTICE OF MEDICAL IMAGING

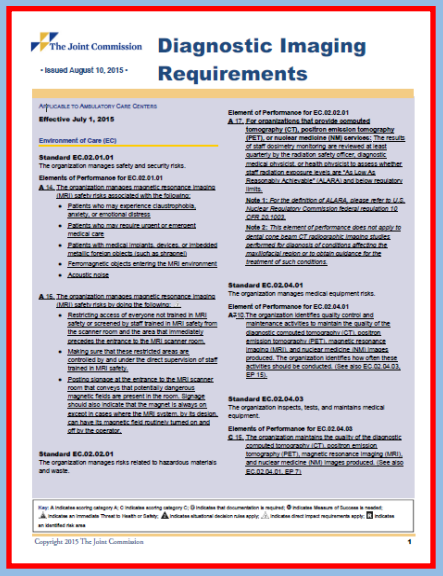
PREAMBLE

This document is an educational tool designed to assist practitioners in providing appropriate radiologic care for patients. Practice Parameters and Technical Standards are not inflexible rules or requirements of practice and are not intended, nor should they be used, to establish a legal standard of care[1]. For these reasons and those set forth below, the American College of Radiology and our collaborating medical specialty societies caution against the use of these documents in litigation in which the clinical decisions of a practitioner are called into question.

The ultimate judgment regarding the propriety of any specific procedure or course of action must be made by the practitioner in light of all the circumstances presented. Thus, an approach that differs from the guidance in this document, standing alone, does not necessarily imply that the approach was below the standard of care. To the contrary, a conscientious practitioner may responsibly adopt a course of action different from that set forth in this document when, in the reasonable judgment of the practitioner, such course of action is indicated by the condition of the patient, limitations of available resources, or advances in knowledge or technology subsequent to publication of this document. However, a practitioner who employs an approach substantially different from the guidance in this document is advised to document in the patient record information sufficient to explain the approach taken.

The practice of medicine involves not only the science, but also the art of dealing with the prevention, diagnosis, alleviation, and treatment of disease. The variety and complexity of human conditions make it impossible to always reach the most appropriate diagnosis or to predict with certainty a particular response to treatment. Therefore, it should be recognized that adherence to the guidance in this document will not assure an accurate diagnosis or a successful outcome. All that should be expected is that the practitioner will follow a reasonable course of action based on current knowledge, available resources, and the needs of the patient to deliver effective and safe medical care. The sole purpose of this document is to assist practitioners in achieving this objective.

[1] Iowa Medical Society and Iowa Society of Anesthesiologists v. Iowa Board of Nursing, ___ N.W.2d ___ (Iowa 2013) Iowa Supreme Court refuses to find that the *ACR Technical Standard for Management of the Use of Radiation in Fluoroscopic Procedures* (Revised 2008) sets a national standard for who may perform fluoroscopic procedures in light of the standard's stated purpose that ACR standards are educational tools and not intended to establish a legal standard of care. See also, Stanley v. McCarver, 63 P.3d 1076 (Ariz. App. 2003) where in a concurring opinion the Court stated that "published standards or guidelines of specialty medical organizations are useful in determining the duty owed or the standard of care applicable in a given situation" even though ACR standards themselves do not establish the standard of care.



The Joint Commission
• Issued August 10, 2015 •

Diagnostic Imaging Requirements

Applicable to Ambulatory Care Centers

Effective July 1, 2015

Environment of Care (EC)

Standard EC.02.01.01
The organization manages safety and security risks.

Elements of Performance for EC.02.01.01

A.16. The organization manages magnetic resonance imaging (MRI) safety risks associated with the following:

- Patients who may experience claustrophobia, anxiety, or emotional distress
- Patients who may require urgent or emergent medical care
- Patients with medical implants, devices, or imbedded metallic foreign objects (such as shrapnel)
- Ferromagnetic objects entering the MRI environment
- Acoustic noise

A.16. The organization manages magnetic resonance imaging (MRI) safety risks by doing the following: ---

- Restricting access of everyone not trained in MRI safety or screened by staff trained in MRI safety from the scanner room and the area that immediately precedes the entrance to the MRI scanner room.
- Making sure that these restricted areas are controlled by and under the direct supervision of staff trained in MRI safety.
- Posting signage at the entrance to the MRI scanner room that conveys that potentially dangerous magnetic fields are present in the room. Signage should also indicate that the magnet is always on except in cases where the MRI system, by its design, can have its magnetic field routinely turned on and off by the operator.

Standard EC.02.02.01
The organization manages risks related to hazardous materials and waste.

Element of Performance for EC.02.02.01

A.17. For organizations that provide computed tomography (CT), positron emission tomography (PET), or nuclear medicine (NM) services: The results of staff dosimetry monitoring are reviewed at least quarterly by the radiation safety officer, diagnostic medical physicist, or health physicist to assess whether staff radiation exposure levels are "As Low As Reasonably Achievable" (ALARA) and below regulatory limits.

Note 1: *For the definition of ALARA, please refer to U.S. Nuclear Regulatory Commission federal regulation 10 CFR 20.1003.*

Note 2: *This element of performance does not apply to dental cone beam CT radiographic imaging studies performed for diagnosis of conditions affecting the maxillofacial region or to obtain guidance for the treatment of such conditions.*

Standard EC.02.04.01
The organization manages medical equipment risks.

Element of Performance for EC.02.04.01

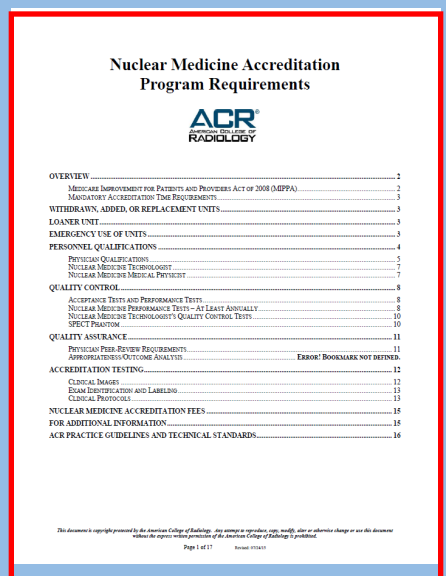
A.3 The organization identifies quality control and maintenance activities to maintain the quality of the diagnostic computed tomography (CT), positron emission tomography (PET), magnetic resonance imaging (MRI), and nuclear medicine (NM) images produced. The organization identifies how often these activities should be conducted. (See also EC.02.04.03, EP 18)

Standard EC.02.04.03
The organization inspects, tests, and maintains medical equipment.

Elements of Performance for EC.02.04.05

A.16. The organization maintains the quality of the diagnostic computed tomography (CT), positron emission tomography (PET), magnetic resonance imaging (MRI), and nuclear medicine (NM) images produced. (See also EC.02.04.01, EP 7)

Key: A indicates scoring category A; C indicates scoring category C; ⊖ indicates that documentation is required; ⊕ indicates Measure of Success is needed; ⚠ indicates an Immediate Threat to Health or Safety; ⚠ indicates situational decision rules apply; ⚠ indicates direct impact requirements apply; ☐ indicates an identified risk area



Nuclear Medicine Accreditation Program Requirements

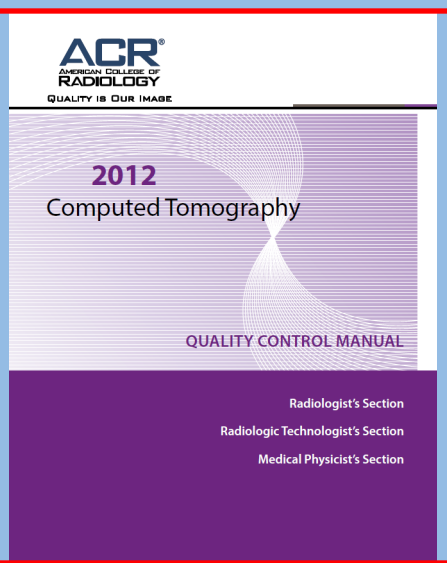
ACR® American College of Radiology

ACR® American College of Radiology
Quality is Our Image

2015
Magnetic Resonance Imaging

QUALITY CONTROL MANUAL

Radiologist's Section
MRI Technologist's Section
Medical Physicist/MRI Scientist's Section

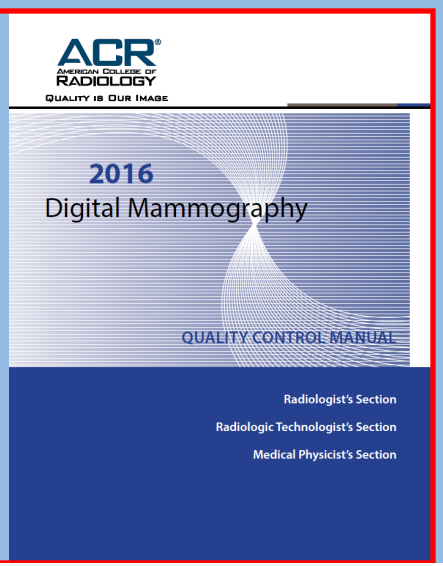


ACR® American College of Radiology
Quality is Our Image

2012
Computed Tomography

QUALITY CONTROL MANUAL

Radiologist's Section
Radiologic Technologist's Section
Medical Physicist's Section

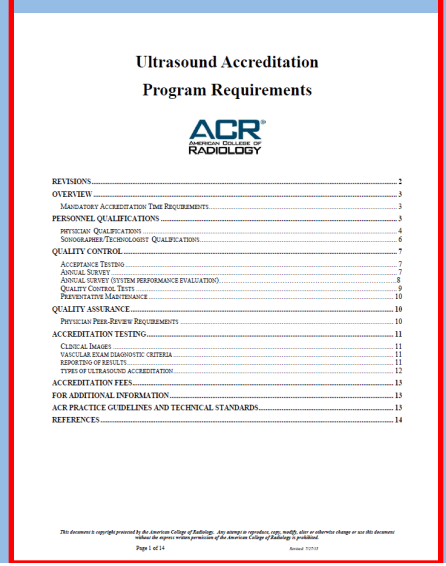


ACR® American College of Radiology
Quality is Our Image

2016
Digital Mammography

QUALITY CONTROL MANUAL

Radiologist's Section
Radiologic Technologist's Section
Medical Physicist's Section



Ultrasound Accreditation Program Requirements

ACR® American College of Radiology

Luminance Response Methodology

TG-270 and ACR-AAPM-SIIM Technical Standard for the Practice of Medical Imaging

1. Determine Lamb
2. Measure Lmin,
   -Ensure Lmin > 4 x Lamb
3. Set L'min determines L'max
   - R_L = 350
4. Determine intermediate gray levels

TABLE II. Estimated Reflection Coefficient Comparison

	Case 1	Case 2
Ambient Illuminance (E)	40 lux	40 lux
Reflection Coefficient (R_d)	0.005 cd/m^2/lux	0.010 cd/m^2/lux
Ambient Luminance (L_{amb})	0.2 cd/m^2	0.4 cd/m^2
Minimum Luminance (L'_{min})	1.0 cd/m^2	2.0 cd/m^2
Maximum Luminance (L'_{max})	350 cd/m^2	700 cd/m^2

The minimum value of L'min is 1.0 cd/m^2

ACR 2016 Digital Mammography QC Manual

Lmin (Modality and Diagnostic)

- Within 30% of manufacturers recommendations or ≤ 1.5 cd/m^2
- Not based on Lamb

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ACR 2016 Digital Mammography QC Manual

Lmax (Modality and Diagnostic)

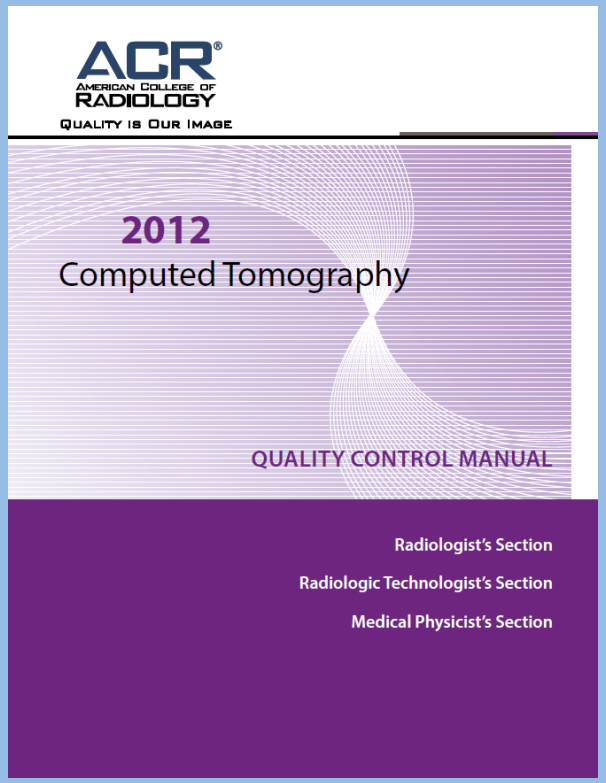
- Within 10% of manufacturers recommendations or
- 150 cd/m^2 (Modality)
- 420 cd/m^2 (Diagnostic)

To maintain a luminance ratio of 350, L'min should be 0.43 cd/m^2 (Modality) and 1.2 cd/m^2 (Diagnostic)

Its difficult to meet the Lmin > 4 x Lamb requirement

ACR – CT (Modality Only)

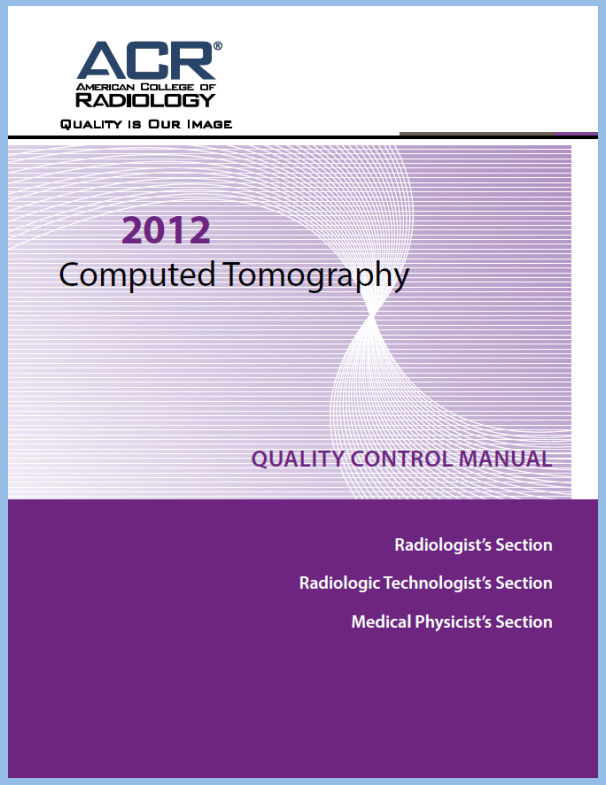
- Visual Evaluation
  - Resolution (via line pairs)
  - Contrast (Both patches visible)
  - Geometric Distortion
  - Black/White Transitions
  - Loss of Bit Depth (Need a gray ramp)



ACR – CT Scanner Monitors

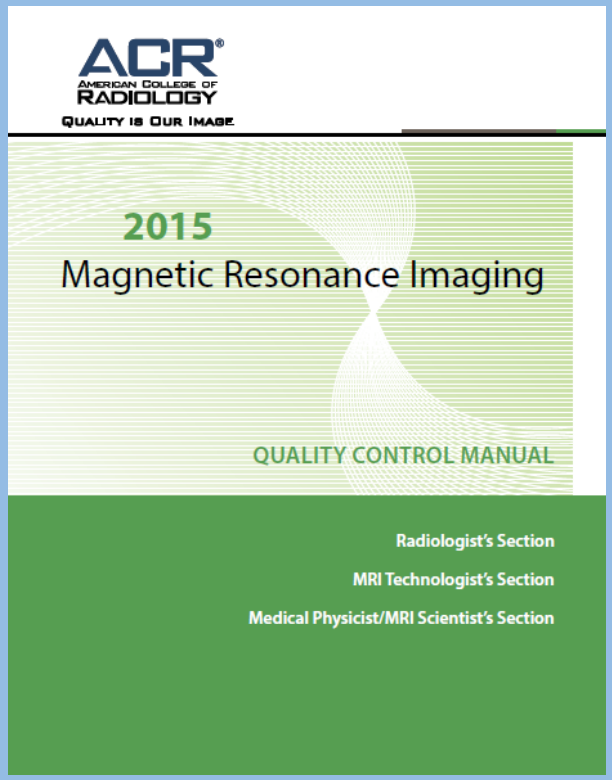
- Quantitative Evaluation
  - Lmin (< 1.2 cd/m^2)
  - Lmax (> 90 cd/m^2)
  - Establish Luminance Response Curve
  - Luminance Uniformity (MLD < 15%)

    (Test Pattern not specified)



ACR – Magnetic Resonance Imaging

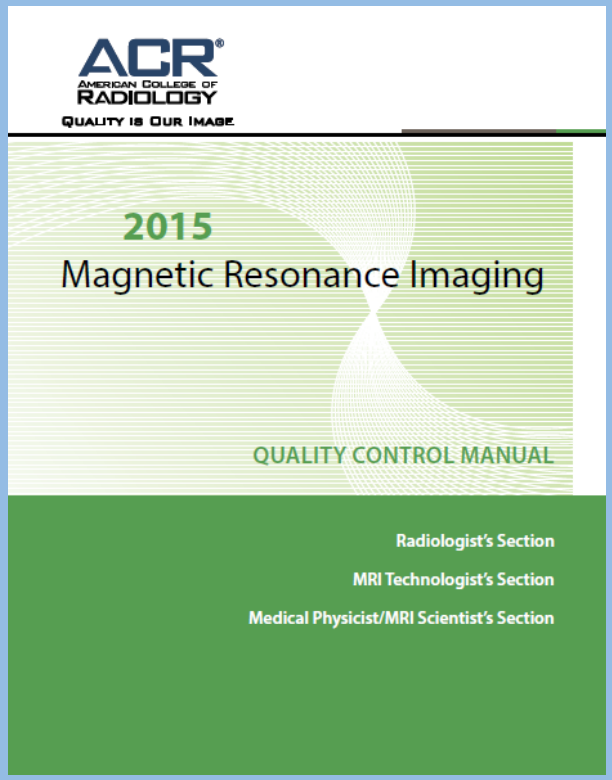
- Visual Evaluation
  - Resolution (via line pairs)
  - Contrast (Both patches visible)
  - Geometric Distortion
  - Black/White Transitions
  - Loss of Bit Depth



ACR – Magnetic Resonance Imaging

- Quantitative Evaluation
  - Lmin (< 1.2 cd/m^2)
  - Lmax (> 90 cd/m^2)
  - ~~Establish Luminance Response Curve~~
  - Luminance Uniformity (MLD < 30%)

    (at Maximum Luminance)



Summary

- Implementation of display QA requirements and recommendations will vary from facility to facility
- Qualified Medical Physicists or other personnel with appropriate training should oversee display QA programs
- Individual sites must determine how to best navigate contradictory guidance