Learning Objectives

- Understanding the relevance of display quality to clinical imaging
- Familiarity with recommendations and requirements for diagnostic displays
- Gain knowledge to
  - Establish display policy and procedure
  - Know what to consider when selecting displays or qc tools
  - Be able to management a display fleet: tactics and tools
THE RELEVANCE OF DISPLAY QUALITY AND QUALITY CONTROL

Image Display

Translating image pixel data into displayed luminance is a type of image processing that can affect image interpretation.

Same image, different display
Image Display

<table>
<thead>
<tr>
<th>Data</th>
<th>Display</th>
<th>Perception</th>
<th>Interpretation</th>
</tr>
</thead>
<tbody>
<tr>
<td><img src="image1.png" alt="Data" /></td>
<td><img src="image2.png" alt="Display" /></td>
<td><img src="image3.png" alt="Perception" /></td>
<td><img src="image4.png" alt="Interpretation" /></td>
</tr>
</tbody>
</table>

- Max luminance
- Min luminance
- Grayscale response (calibration)
- Color
- Illuminance, reflection
- Resolution
- Noise and Uniformity
- Temporal response

Goals for Image Display

- **Maximize the visibility of information in one view**
  - There is more information in an image than can be seen at one time
  - Lose as little as possible
  - While we can zoom/pan, and window/level, this reduces efficiency, and search is guided by what can be seen at one time.
- **Consistent presentation of images**
  - Image processing is designed and modified for specific purposes. We want the result to be consistent between different workstations
Displays- Set it and forget it?

- Backlights age (dim)
- Front panels age (opacity changes)
- Pixels can become stuck
- Panels can become damaged
- Incorrect calibrations can be applied
- Cabling can go bad or be disconnected
- Miscommunication or poor settings between display driver, display software, and display can result in artifacts and reduced resolution (contrast or spatial).

= need for quality control

Why me (a medical physicist)?

- We’re good at understanding technology and how it relates to image quality.
- If we don’t already know how displays work, we can learn this*
- We manage and conduct QC testing as relates to standards and accreditation

RECOMMENDATIONS AND REQUIREMENTS FOR DIAGNOSTIC DISPLAYS

What are we aiming for?

- Diagnostic displays in NY state and those for mammography (MQSA) have specific settings and QC requirements
What are we aiming for? - Mammography

Know what manual you should follow.

*If you are unsure contact MQSA.*

- Are you using the ACR FFDM QC manual?
- Are you following your FFDM manufacturer’s QC manual?
  - If the FFDM manufacturer defers ..... 
  - Does your PACS or reading mammography workstation have a QC manual?
  - Does your mammography display manufacturer have a QC manual?

What are we aiming for? – Other diagnostic monitors

ACR accreditation programs have minimal or no requirements for diagnostic displays outside of mammography.

<table>
<thead>
<tr>
<th>ACR CT 2017 QC manual</th>
<th>ACR US Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>While photometric evaluation of workstations is vital, establishment of an appropriate quality control program for diagnostic workstations is beyond the scope of this document. Each facility should work with its workstation manufacturer(s) and its medical physicist to establish an appropriate and effective quality control program for the diagnostic workstations under their purview.</td>
<td></td>
</tr>
<tr>
<td><strong>QC Test</strong></td>
<td></td>
</tr>
<tr>
<td>5. Primary Interpretation Display Performance* (Optional)</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ACR MRI 2015 QC manual</th>
</tr>
</thead>
<tbody>
<tr>
<td>A soft-copy QC program should be in place for all diagnostic workstations. The specifications for such a QC program are outside the scope of this document.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ACR NM QC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Monitor Evaluation</td>
</tr>
<tr>
<td>Performed to ensure that systems used to produce hard copy and monitors that are used for interpretation of clinical studies provide satisfactory image quality in terms of uniformity and spatial resolution.</td>
</tr>
<tr>
<td>defined but not required</td>
</tr>
</tbody>
</table>

Lack of requirements of consequence makes it challenging for a physicist advocating for a practice to “establish an appropriate and effective QC program” when this translate to $$$
What are we aiming for? – Other diagnostic monitors

*What standard should we look to?*

The ACR–AAPM–SIIM TECHNICAL STANDARD FOR ELECTRONIC PRACTICE OF MEDICAL IMAGING provides guidance for

- Equipment choice
- Display settings

https://www.acr.org/-/media/ACR/Files/Practice-Parameters/elec-practice-medimag.pdf

What are we aiming for? – Other diagnostic monitors

*What standard should we look to?*

The AAPM TG 270 report “Display Quality Assurance” provides guidance on *how* to provide display quality assurance

*The AAPM TG270 report and the ACR-AAPM-SIIM Technical Standard are aligned in their aims for display performance*

https://www.aapm.org/pubs/reports/RPT_270.pdf
What are we aiming for? – Other diagnostic monitors

From the AAPM TG270 report

<table>
<thead>
<tr>
<th>TABLE VI. Recommended Display Luminance Levels</th>
</tr>
</thead>
<tbody>
<tr>
<td>Display Type (non-mammography)</td>
</tr>
<tr>
<td>Recommended Values* [Acceptable Ranges]</td>
</tr>
<tr>
<td>Diagnostic Displays</td>
</tr>
<tr>
<td>L'_{min} ≥ 1.0 cd/m²</td>
</tr>
<tr>
<td>LR = 350 [250 - 450]</td>
</tr>
<tr>
<td>L'_{max} = 350 cd/m² [≥ 300 cd/m²]</td>
</tr>
</tbody>
</table>

* All recommended values assume an ambience ratio (L_{amb}/L_{min}) of 1/4 or smaller.

This is generally achievable in reading environments with recommended range of ambient illuminance : 25–75 lux

\[
L'_{min} = L_{min} + L_{amb}
\]

\[
L'_{max} = L_{max} + L_{amb}
\]

\[
L_{amb} = R_d \cdot E
\]

Typical values of R_d range from 0.002 to 0.010 cd/m²/lux, though higher values are possible with glossy displays or protective panels.

For display calibration, pick a reasonable ambient light you can accommodate in the range 25-75 lux such that

\[
LR = \frac{L'_{max}}{L'_{min}} = \frac{L_{max} + L_{amb}}{L_{min} + L_{amb}} \approx 350 \cdot [250 - 450]
\]

An note on dealing with ambient light

<table>
<thead>
<tr>
<th>TABLE VII. Recommended Display Luminance Response Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td>Display Type</td>
</tr>
<tr>
<td>Recommended Limits*</td>
</tr>
<tr>
<td>Diagnostic Displays</td>
</tr>
<tr>
<td>Deviation in either JND/GL or dL/L per JND from DICOM GSDF ≤ 10%</td>
</tr>
</tbody>
</table>

Luminance Ratio

\[
LR = 350
\]

Estimated Reflection Coefficient

<table>
<thead>
<tr>
<th>Ambient Illuminance (E)</th>
<th>Reflection Coefficient (R_d)</th>
<th>Ambient Luminance (L_{amb})</th>
<th>Minimum Luminance (L'_{min})</th>
<th>Maximum Luminance (L'_{max})</th>
</tr>
</thead>
<tbody>
<tr>
<td>40 lux</td>
<td>0.005 cd/m²/lux</td>
<td>0.2 cd/m²</td>
<td>1.0 cd/m²</td>
<td>350 cd/m²</td>
</tr>
</tbody>
</table>

L_{amb} = R_d \cdot E
Designing your Display Program

Where there isn’t regulatory or accreditation requirement, it is up to each practice to set their own policies and procedures for “appropriate and effective” diagnostic display setting and quality control.

Both the ACR-AAPM-SIIM Technical Standard and the AAPM TG 270 report provide guidance.
Establish display aims with your practice

Ensure there is agreement on anything that entails $$, e.g.:

• Scope (which workstations?)
• Target Display settings (e.g., follow AAPM/ACR/SIIM standard)
• What type of equipment you can support
  – i.e. Display features like stabilized backlight or integrated photometer for remote cal/QC
• Display QC Plan (including failure/replacement threshold)

Scope: Diagnostic Displays

“Diagnostic displays are where medical images are displayed for primary interpretation ………

Users may also use the diagnostic display category when deciding how to characterize the desired performance of any display that is used to perform primary interpretation or make routine medical diagnoses or decisions (e.g., modality displays for angiographic or ultrasound systems).”

Scope: What about remote or home workstations?

“Diagnostic displays are where medical images are displayed for primary interpretation .......... 

If the requirements are defined by purpose. and the purpose is the same in location A as location B, then the requirements for location A and location B are the same.

The remote fleet

Home workstations are increasingly important to radiology practices

Whether coping with a pandemic, timely “on-call” diagnosis, or flexible staffing

Video of Dr. Nicholas Morley, MD.
Marshfield Clinic Health Systems
EXAMPLE: What type of equipment we will support?

Selection by imaging informatics committee includes:
- Physics and PACS team evaluation
- Radiologist evaluation
- Budgeting
- Requirements for supportability

Example selection criteria for new displays:
- **Must be able to meet ACR-AAPM-SIIM Technical Standard for diagnostic display**
- Other priorities:
  - Integrated photometer for remote support
  - Stabilized backlight
  - Pixel based uniformity correction (low added noise)
  - Low reflectivity so we can keep rooms brighter and maintain desired luminance ratio
  - Monitor based LUT (can calibrate then distribute or swap workstations without issue, great for home displays used with laptops)
  - Compatible with existing video cards or coordinated with refresh

Display Selection Considerations

Meeting ACR-AAPM-SIIM Technical Standard recommendations for diagnostic display

<table>
<thead>
<tr>
<th>Display Type</th>
<th>Recommended Values [Acceptable Ranges]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Diagnostic Displays (non-mammography)</td>
<td>$L'_\text{min} \geq 1.0 \text{ cd/m}^2$</td>
</tr>
<tr>
<td></td>
<td>$L_\text{R} = 350 \text{ [250 - 450]}$</td>
</tr>
<tr>
<td></td>
<td>$L'_\text{max} = 350 \text{ cd/m}^2 \geq 300 \text{ cd/m}^2$</td>
</tr>
</tbody>
</table>

*Some higher-end consumer [off-the-shelf ] displays may meet these criteria*, many will not

*Medical grade“ displays sold for diagnostic use will meet these criteria

*Many “Medical grade“ displays sold for clinical use can meet these criteria*

*you’ll need to validate this for yourself*
Display Selection Considerations

Meeting ACR-AAPM-SIIM Technical Standard recommendations for diagnostic display

Caution: an advertised brightness of 350 cd/m² DOES NOT MEAN it can be calibrated to 350 cd/m². Pixels may be dimmed in order calibrate to GSDF. Luminance cost must be validated per display (may be around 5%).

For consumer-grade displays, the ability to achieve a targeted calibrated max luminance is not guaranteed, you’ll need to test it.

Calibration = setting the display LUT to produce the desired max and min luminance, the luminance response function and color.

Display Selection Considerations

How many years can a display meet ACR-AAPM-SIIM luminance criteria?

- Backlights dim with use.
- Backlight “headroom” (overage) + recalibration and/or backlight stabilization is needed to maintain a stable luminance response over time.
- LEDs typically stay brighter longer than CCFL

Rate of degradation will depend on the particular LCD panel and backlight.

Maximum Display Luminance, LED and CCFL

![Graph showing maximum display luminance for LED and CCFL over hours of operation]
Display Selection Considerations

How many years can an LED backlit display meet the desired luminance criteria*?

High-end consumer display
Initial calibration for typical reflectivity and 25 lux
• L’max = 330 cd/m² max
• L’min = 1 cd/m² min
• LR = 330

Maximum Brightness 350 cd/m²

Assuming LED backlight decline of “brand x, model A”

Actual backlight-limited lifetime will vary with specific LCD Panel and backlight
It could work for 15 K hours with max calibrated luminance of 300 cd/m², but you’re going to have to validate this yourself.

Medical Grade Display
Initial calibration:
• L’max = 400 cd/m² max
• L’min = 1 cd/m² min
• LR = 400

Estimated backlight life providing > 30K hours is not unreasonable for some displays.
Data from some managed displays shows usage times of ~60K hours with displays still meeting desired specifications

Guaranteed to make calibration for at least 20k hours. Typical backlights lasts much longer

*with regular calibration
Display Selection Considerations

How frequently do displays need to be calibrated?

depends on display stability and tolerance for white point variation*

- Consumer-grade displays with unstabilized backlights or displays without headroom will dim over time.
- Medical-grade displays with stabilized backlights still need regular calibration to compensate for change in color and opacity as LCD panel ages.
- Newer LED backlights are more stable than older CCFL backlights

Without Recalibration


Display Selection Considerations

How frequently do displays need to be calibrated?

- Medical Grade display vendors may recommend a calibration frequency (typically twice per year).
- The stability of modern, unstabilized, LED–backlit consumer grade displays needs to be studied to establish appropriate calibration frequency.

- AAPM TG270 Report recommends luminance assessment quarterly and quantitative testing annually (with a photometer).
  - If easier, quantitative could be done quarterly, and qualitative annually.
  - Calibration (and verification ) could be done in place of quantitative testing.
Display Selection Considerations

<table>
<thead>
<tr>
<th>Handheld photometer</th>
<th>Display integrated photometer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Requires in person calibration or testing</td>
<td>Calibration and testing scheduled to run automatically. Can be run overnight.</td>
</tr>
<tr>
<td>TG270 luminance response testing recommendations</td>
<td></td>
</tr>
<tr>
<td>Qualitative 4 times per year</td>
<td>Qualitative annually</td>
</tr>
<tr>
<td>Quantitative annually</td>
<td>Quantitative 4 times per year</td>
</tr>
<tr>
<td>How much time to you have for display QC? How much access do you have to workstations?</td>
<td>What’s your budget?</td>
</tr>
</tbody>
</table>

Display QC software considerations

Software installed on each workstation for display calibration and quality control testing

Video card calibration
- Can work with any display
- Needed for consumer-grade displays
- Examples:
  - pacsDisplay (https://pacsdisplay.org/)
  - Barco MediCal QAWeb

Monitor-based LUT calibration
- Requires the display vendor’s QC software*
- Available with medical-grade displays
- Helpful if using laptops to drive remote workstations
- Examples:
  - Eizo RadiCS
  - Barco MediCal QA Web agent
  - X-Cal
  - CFS Calibration Feedback System

Either type will have requirements for compatible photometer
* Or vendor validated
Display QC software considerations

QC Management Software

Typically a web-based application that

Collects display calibration and QC reports.
- Provides reporting of continual compliance from tests run by workstation-installed QC software
- Can be setup to generate alerts for non-compliance
- Some provide monitoring for compliance with a scheduled QC program

If coordinated with workstation-installed QC (client) software, it can be used to:
- Set display calibration and quality control policies
- Schedule and push out automated calibration and tests

Examples: Radinet Pro, QA Web (Enterprise), X-Cal, CFS, QC track
Display Program Example- Overview

*Marshfield Clinic Health System*

Managed by the physics group

- Display settings and QC Plan outlined for each display model
- Written procedures are provided for: installation, acceptance test, and quality control
- Vendor client software is used for calibration and quality control testing.
- Vendor QC management software is used for automated testing, alerts, and saving of QC reports
- Off-line display inventory (spreadsheet) used to track fleet changes and to ensure annual completion of all QC tasks.
- Annual reports of fleet compliance and budget estimates (for projected backlight failures) are provided to Imaging Informatics Committee

---

Example Display Calibration Settings:

*Marshfield Clinic Health System*

<table>
<thead>
<tr>
<th>Display Targets</th>
<th>max luminance (cd/m^2)</th>
<th>typical black level, no ambient</th>
<th>Luminance Ratio with standard ambient</th>
<th>max lum failure threshold (cd/m^2)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Display Model</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full System</td>
<td>400</td>
<td>0.72</td>
<td>400</td>
<td>376</td>
</tr>
<tr>
<td>40”</td>
<td>400</td>
<td>0.63</td>
<td>400</td>
<td>376</td>
</tr>
<tr>
<td>46”</td>
<td>400</td>
<td>0.8</td>
<td>400</td>
<td>376</td>
</tr>
<tr>
<td>55” (home)</td>
<td>350</td>
<td>0.63</td>
<td>350</td>
<td>330</td>
</tr>
<tr>
<td>(home) *</td>
<td>200</td>
<td>Equalized (typical .21-.23)</td>
<td>385</td>
<td>188</td>
</tr>
<tr>
<td>(mammo)</td>
<td>900</td>
<td>Equalized (typical 1.2)</td>
<td>643</td>
<td>846</td>
</tr>
<tr>
<td>(mammo)</td>
<td>600</td>
<td>0.64</td>
<td>723</td>
<td>564</td>
</tr>
<tr>
<td>(mammo)</td>
<td>500</td>
<td>0.6</td>
<td>625</td>
<td>470</td>
</tr>
</tbody>
</table>

All calibrated to the DICOM GSDF with assumed ambient illumination of 40 lux

Following guidance from ACR-AAPM-SIIM Technical Standard

*older monitors that met the standard when purchased*
Example Display QC plan

From the Marshfield Clinic Health System

<table>
<thead>
<tr>
<th>Vendor</th>
<th>Display Model</th>
<th>Location</th>
<th>Visual Test by physics or PACS</th>
<th>Display Calibration (within 6% of white target)</th>
<th>DICOM conformance check (within 10% of GSDF)</th>
<th>Visual test or Visual Confidence check by user</th>
</tr>
</thead>
<tbody>
<tr>
<td>Barco</td>
<td>MDNC-3421</td>
<td>on-site reading room</td>
<td>Annual</td>
<td>semiannual</td>
<td>quarterly</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>MDNC-3421</td>
<td>home workstation</td>
<td>At install</td>
<td>semiannual</td>
<td>quarterly</td>
<td>None</td>
</tr>
<tr>
<td>Barco</td>
<td>MDCC 6130</td>
<td>on-site reading room</td>
<td>Annual</td>
<td>semiannual</td>
<td>quarterly</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>MDCC 6130</td>
<td>home workstation</td>
<td>At install</td>
<td>semiannual</td>
<td>quarterly</td>
<td>None</td>
</tr>
<tr>
<td>Barco</td>
<td>MDNC-3121</td>
<td>on-site reading room</td>
<td>Annual</td>
<td>annual if needed</td>
<td>Annual</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>MDNC-3121</td>
<td>home workstation</td>
<td>At install</td>
<td>backlight cal semiannual</td>
<td>None</td>
<td>Annual*</td>
</tr>
<tr>
<td>Barco</td>
<td>MG-5221</td>
<td>on-site reading room</td>
<td>Annual</td>
<td>semiannual</td>
<td>quarterly</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>MG-5221</td>
<td>home workstation</td>
<td>At install</td>
<td>semiannual</td>
<td>weekly</td>
<td>Annual</td>
</tr>
<tr>
<td>Barco</td>
<td>MG-5221</td>
<td>on-site reading room</td>
<td>Annual</td>
<td>semiannual</td>
<td>weekly</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>MG-5221</td>
<td>home workstation</td>
<td>At install</td>
<td>semiannual</td>
<td>weekly</td>
<td>Annual</td>
</tr>
<tr>
<td>Eizo</td>
<td>RX360</td>
<td>on-site reading room</td>
<td>Annual</td>
<td>semiannual</td>
<td>weekly</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>RX360</td>
<td>home workstation</td>
<td>At install</td>
<td>semiannual</td>
<td>weekly</td>
<td>Annual*</td>
</tr>
<tr>
<td>Eizo</td>
<td>X1270</td>
<td>on-site reading room</td>
<td>Annual</td>
<td>semiannual</td>
<td>weekly</td>
<td>None</td>
</tr>
<tr>
<td></td>
<td>X1270</td>
<td>home workstation</td>
<td>At install</td>
<td>semiannual</td>
<td>weekly</td>
<td>Annual*</td>
</tr>
</tbody>
</table>

Mammography

<table>
<thead>
<tr>
<th>Location</th>
<th>Visual Test by physics or PACS</th>
<th>Display Calibration (within 6% of white target)</th>
<th>DICOM conformance check (within 10% of GSDF)</th>
<th>Visual test or Visual Confidence check by user</th>
</tr>
</thead>
<tbody>
<tr>
<td>on-site reading room</td>
<td>Annual</td>
<td>semiannual</td>
<td>quarterly</td>
<td>None</td>
</tr>
<tr>
<td>on-site reading room</td>
<td>Annual</td>
<td>semiannual</td>
<td>quarterly</td>
<td>None</td>
</tr>
<tr>
<td>home workstation</td>
<td>At install</td>
<td>semiannual</td>
<td>quarterly</td>
<td>None</td>
</tr>
<tr>
<td>home workstation</td>
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<td>semiannual</td>
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<td>None</td>
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<td>Annual</td>
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<td>Annual</td>
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<tr>
<td>on-site reading room</td>
<td>Annual</td>
<td>semiannual</td>
<td>weekly</td>
<td>Annual</td>
</tr>
<tr>
<td>home workstation</td>
<td>At install</td>
<td>semiannual</td>
<td>weekly</td>
<td>Annual</td>
</tr>
</tbody>
</table>

Example Display QC plan-Luminance Response Test

Built-in photometer
All newer monitors
- Enables remote, overnight test and calibration at desired frequency
- Integrated photometer may need recalibration.* Check at acceptance and at ~10k hours (TG270)

No built-in photometer
Legacy displays only
- Requires in-person visit
- Requires interruption of radiologist or off hours

Our compromise
on site: calibrate/test at install then once a year or at hardware change
Remote: calibrate/test at install, then rely on backlight calibration and visual tests

*End-user Visual Confidence test

Example Display QC –other tests

Marshfield Clinic Health System

1. Luminance Uniformity: measured quantitatively with a hand-held photometer at acceptance otherwise anything we care about for QC we catch in visual test

2. Artifact- visual test at acceptance and for QC

3. Color- set quantitatively at install. Look for color tracking or nonuniformity issues during QC with visual test

4. Noise- on evaluation with visual test or low noise, high res camera if available.

Test we ignore: Geometric accuracy
LCD (fixed array) pixels don’t move around!
-Bad measurements are interoperability issues with modality and PACS, not the monitor (catch that with interoperability tests TG248)

Example Display QC –Visual Test

Marshfield Clinic Health System

Performed by physics (at QC) or PACS (at install) or tech as needed

Things to check
1. Were there artifacts seen on UN-80 pattern (fail)?
2. (red box): Is the grayscale smooth (pass) or do you see jumps/lines (fail)?
3. Can you see distinct lines (pass)? Or are they blurred into each other (fail)?
4. Are borders between black and white crisp (pass) or any overshoot, bleeding from black to white or vice-versa? (fail)?
5. Can you see the 4 corner boxes in each of the 16 squares (yes=pass, no=fail)?
6. Can you visualize the 5% contrast boxes (yes=pass, no=fail)?
7. If you can pass all the above then hit enter to respond to all the pattern evaluation questions.
8. Otherwise fail the most closely related prompt and comment on the failure.

for artifact check and visual non-uniformity

Newer Test patterns tailored for LCD introduced in TG270 report
Did we do what we said we would do?

Example Display QC Management

Did we do what we said we would do?

Example Display QC – Remote Diagnostic Workstation

For remote workstations, it’s reasonable to train radiologists to perform qualitative evaluations for QC.*

Our approach:

- Displays calibrated and checked before sending out
- PACS does visual test at install.
- Radiologists are asked to do a Visual Confidence Check for QC (non-mammo DX) and the results are viewable on the QC management application
- Physics monitors remote quantitative testing from built-in photometer if present

Radiologists are provided prompts and instructions. Non-passing results are compared to on-site results

*Silosky, Michael et al. Features to Consider When Selecting Displays for Remote Reading. JACR (2021)
Example Display QC – Remote Diagnostic Workstation

Using a “forced choice” Visual Confidence Test for Radiologist QC of displays

3. You will be prompted to find the object for a series of difference background luminance values. For each, you must select the displayed object on the bottom bar:

4. For a properly calibrated display, with adequate max and minimum luminance and environmental lighting, the objects should be equally visible on all backgrounds. The objects may still be challenging to find.

Video of Dr. Nicholas Morley, MD. Marshfield Clinic Health Systems

Remote Diagnostic Workstation-Visual Test

My take on end-user visual tests

Forced Choice – Visual Confidence Checks

Test Patterns

CAPTCHA

EULA
Example Display QC –Mammography Specific QC

Know what manual you should follow.
If you are unsure contact MQSA.

We follow the Sectra QC Manual which defines what needs to be done by who and when.

The Sectra QC manual does not require annual in-person QC by a QMP*. This can be delegated. For our practice, our delegates are trained and overseen by physics.

*On-site physics evaluation required at other instances in the manual, but per communication with the vendor can be delegated.

Example Display QC –Remote, Mammography Specific QC

For Sectra PACS, MCHS QC approach

Annual Display QC

• Calibration and luminance response is tested (automatically) by the display software and integrated photometer. Results are reviewable remotely by QMP.
• In-person tests are performed by radiologists* who
  – Provide room schematic
  – Do ambient light checks
  – Do visual tests
• QMP completes the annual display testing report.

* Prompted and coached by physics
Example Display QC – Remote, Mammography Specific QC

For Sectra PACS, MCHS QC approach

Weekly and Daily Display QC

The designated Mammo QC technologists take responsibility for logging compliance with weekly and daily display QC checks.

For weekly check:
- Technologists verify weekly compliance test has run

For daily check:
- Radiologist communicate with technologists about days when used and that monitor has been cleaned and ambient lighting has not changed.

Example Display QC – Mammography Specific QC

Know what your manual requires.

If you follow a display manufacturer or review workstations vendor’s manual that does not permit delegating visual tests, and you feel that is appropriate for your practice, consider asking them for a letter endorsing a variance.
DISPLAY MANAGEMENT ADVICE FROM A PACS ADMINISTRATOR

From Dan Turzinski

Display management Advice from a PACS admin

• Know how to do the client install (workstation QC software)
  – Silent push? Need for manual install?
  – Know what information needs to manually configured within the client app after install:
    - Server connection, assigned to correct QC policy, Room location, ambient light setting, etc.

• Create a good organizational structure on the Fleet management software
  – Create a structure that will help with assigning the correct calibration and QC policy (e.g. Mammo vs other, or by Clinic site or home workstation group).

Alisa’s added commentary:

You’ll need to know how your fleet management software assigns policies in order to set this up appropriately.
Recommendations for successful deployment

1. Use the graphics cards validated by the display vendor
2. Connect monitors according to vendor recommendation (i.e., USB cabling for communication between client software and display)

In the operating system’s display settings:

3. Appropriately setup ordering and alignment of monitors for multihead workstation
4. Define appropriate scaling and resolution

5. Work with physicists to establish a procedure for applying the appropriate calibration and QC settings, and for what calibration and testing needs to be done at display installation.
Problems encountered during installation

• Certain monitors required special cabling
• Scaling and resolution did not work with PACS application*

*many PACS systems require 100% scaling and correct monitor resolution to display images fully across the screen i.e. Sectra, Syngo Dynamics

Automated tests aren’t running or failed, what happened?

• The computer is being turned off overnight or for an extended period
• USB cabling between monitors is unplugged, non-existent or the cable is bad
• The display was calibrated before the display policy synchronized (i.e. calibrated to the wrong settings) and after synchronization QC tests fail
• Monitors aren’t detected on the server. This may require them to be disconnected from all power sources for several minutes to force them to check back in, and may require manual “display detection”.
Automated tests aren’t running or failed, what happened?

For Home workstations:
- Internet issues (have user contact ISP)
- VPN firewall not allowing communication with the server
  - User needs to be logged in (for VPN connection) for tests to be pushed (not required on clinic network). Depending on how the display vendor pushes out automated tests, tests may not run until the user logs in.
- VPN needs to be restarted
- Software updates didn’t run for extended period of disuse and bog down the system until multiple reboots finalize the updates

Dan’s words of wisdom

Call the vendor after you’ve stepped through your trouble-shooting and still have communication problems with the display management server
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Questions?