

Calibration in Medical Imaging  
White Paper  
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Why is the topic of calibration important?

Calibration of a soft-copy viewing station is an important component of effective medical imaging.

The calibration precision required is a function of several considerations (modality, type of anatomy being imaged, diagnostic or clinical use, etc.)

In many cases, there are very small luminance differences between an area of interest (which itself may be very small) and the surrounding area. Without proper attention to display system calibration (as well as the resolution), it is possible that the viewing workstation itself can adversely affect the ability to make a proper diagnosis or interpretation of the image being displayed. For example, if one used an uncalibrated commercial color monitor, the low-level shades of gray may be particularly hard to distinguish from one another. Clearly, it is unacceptable to have a diagnosis be compromised depending on which viewing station is used to view the image. With the calibration tools available today for medical grade viewing stations, this compromise can be avoided.

Guidelines:

Given the importance of properly displaying medical images, there have been several guidelines that have been developed around the topic of calibration.

When the American College of Radiology (ACR) and National Electrical Manufacturers Association (NEMA) formed a joint committee to develop a Standard for Digital Imaging and Communications in Medicine (DICOM), they reserved Part 14 for the Grayscale Standard Display Function. This standard defines a way to take the existing Characteristic Curve of a display system (i.e. the relationship between the Luminance Output for each Digital Driving Level or pixel value) and modify it to the Grayscale Standard Display Function. At the heart of the Grayscale Standard Display Function is the Barten Model. This model takes into account the perceptivity of the human eye. Given the black and white levels of the display system, it will spread out the luminance at each of the intermediary Digital Driving Levels such as to maximize the Just Noticeable Differences between each level. The bottom line is that after calibration, each Digital Driving Level will be most distinguishable from the other throughout the luminance range, and it will be consistent with other display systems that are similarly calibrated. When a high contrast, medical grade display is used in combination with the calibration procedures described in DICOM, it will result in consistent, optimized images. The reader is encouraged to review the DICOM Part 14 document in detail for more information. (The document can be found at [www.nema.org](http://www.nema.org) ).

The American Association of Physicists in Medicine (AAPM) Task Group 18 is a national task force whose purpose is to generate a document that provides guidelines to practicing medical physicists and engineers for in-field performance evaluation of electronic display devices intended for medical use. The document includes a family of test images that can be used either visually, or in conjunction with test equipment to evaluate the performance of a display system. The user needs to tailor the tests based on whether a CRT based or LCD based display system is used. (A draft of the existing document can be found at <http://deckard.mc.duke.edu/~samei/tg18> ).

### CRT vs LCD:

Both CRT-based and LCD-based display monitors have been successfully used in medical imaging applications. There are advantages and disadvantages to each technology. An LCD display does not have many of the geometrical distortions and artifacts that can be present on a CRT display and has become the preferred workstation display for many PACS reading stations. There are some tradeoffs however. For example, the black levels of a LCD are not as black as a CRT, there are viewing angle considerations and dead pixel artifacts that are not an issue with CRT displays.

From a calibration standpoint, a LCD-based display is typically more stable than a CRT-based display. A CRT can have variations from the electron gun, phosphor, and power supply that will disturb brightness settings and calibration. The LCD's primary source of variation is the backlight, although temperature, ambient lighting changes, and shock/vibration will also have effects. The characteristic curve of an uncalibrated LCD is poor, especially in the low-level gray shade regions. It is important to implement an initial DICOM correction before utilizing the display for diagnosis. Following the implementation of the initial DICOM correction, (typically done via a Look-up Table or LUT), periodic measurements should be made to ensure that the calibration correction is still accurate. Calibration should be performed after transportation of the display which can disrupt the mechanical stresses on the LCD material and cause shifts in the characteristic curve of the display.

### Liability concerns:

While the primary benefit that calibration tools provide are the improved images and improved consistency of how the images are displayed, the tools also help provide a benefit in the area of liability. It is recommended that institutions be prepared to show that they have properly implemented calibration into their medical imaging process. This involves the documentation of objective evidence that the viewing stations have been properly calibrated in a timely manner, per good industry practice. An unwillingness to properly address the calibration issue, could result not only in compromised images, but open up a liability risk that an opposing attorney can take advantage of.

### Calibration Tools:

Manufacturers of display systems for medical use have developed both hardware and software tools to enable the users at the hospital or radiology clinics to fulfill their responsibility that they are using properly calibrated displays.

The display system consists of a video graphics card and display monitor. A DICOM compliant display system would mean that there is the capability to generate a LUT that would correct the Characteristic Curve per the DICOM Grayscale Display Function.

The Image-XMP series of video graphics cards come with a DICOM compliant LUT preloaded into the card. It is an average LUT, compiled from data from many displays, which enables the user to have a much better DICOM correction right out of the box than if there was none at all. The software drivers for the Image-XMP series include a series of visual test patterns that are useful for a quick check and reassurance that all is well. This includes the familiar SMPTE test pattern as well as quick access to the TG18 test patterns. (A quick check might include making sure both 5% squares on the SMPTE pattern are viewable. If they are not, as is often the case on commercial color LCDs, there is something grossly wrong with the calibration).

A handheld luminance meter (sometimes referred to as a "puck") is used to measure the conformance to the DICOM standard and, when used in conjunction with calibration software, provides the data to generate a custom LUT correction for DICOM Grayscale Display Function compliance. A user doing this on site will take into consideration the peculiarities of the particular display and the particular environment in which it is being used.

In the Image Systems line of medical LCD monitors, there is a luminance sensor built into the back of the display. There is Stable Backlight Control (SBC) circuitry, which on a closed loop basis, monitors the

luminance of the backlight and makes adjustments to the control voltage to keep the backlight consistent. This is useful for backlight variations that occur during display warm-up time and well as reductions in backlight output that occur over time. A combination of a DICOM compliant LUT with backlight control circuitry on an LCD monitor is a powerful set of tools to keep the displays in good working order.

Additional control can be attained with the use of front luminance sensors. These can be permanently mounted, or can move out of the bezel so that there is a measurement position and a park position which does not block any of the viewing area. A front sensor enables the measurement of the characteristic curve on a hands-free basis.

Sophisticated calibration software, such as the Image Systems CFS (Calibration Feedback System) can be used to schedule when a conformance check occurs (off hours for example). It can adjust the backlight. It can generate a new DICOM correction LUT if needed. And there is log of tests and activity that is generated providing a verifiable record of compliance testing. A tightly integrated display system with display, video graphics card, and calibration hardware and software can eliminate or greatly reduce the need for technicians to take manual measurements. Finally, calibration software can be network enabled such that an administrator can review and manage the calibration status of all of the monitors he/she is responsible for from one desk, even if the monitors are located at remote sites. Simple Network Management Protocol (SNMP) is a powerful, secure tool frequently used for this purpose.