

# REQUIREMENTS FOR MEDICAL IMAGING MONITORS (part I)

*By Ken Compton and Herman Oosterwijk*

The question of what monitor to use for diagnostic purposes with digital medical images has been a recurring theme ever since these images were first generated. Variations on this theme are: Can I use a commercial monitor for diagnosing medical images? Is a 3-megapixel (MP) display sufficient to look at chest radiographs? Related questions that we are often asked are: How should I calibrate these monitors? What is the impact of environmental light on the diagnostic capability of displays in the ER or the ICU?

This white paper provides practical guidelines for the selection of the right monitor for the right diagnostic application. We also will describe how to keep your monitor operating at diagnostic quality. In addition, we provide an introduction to the characteristics of displays and the key parameters that describe monitor performance.

## TERMINOLOGY NEEDED TO UNDERSTAND MONITOR PERFORMANCE

Defining image quality involves a number of metrics. These range from terminology created before the invention of the incandescent light to the modern definitions found in DICOM Part 14, Grayscale Standard Display Function (GSDF). Some of the terms still in use were developed for analog TV. Their use in application to Liquid Crystal Displays (LCD's) can lead to some errors in understanding. As the Cathode Ray Tube (CRT) has—for the most part—departed as a medical imaging display platform, the following explanations are focused on LCD technology.

- **Luminance**

*Luminance* is the correct term for photon energy that reaches the eye; it is **not** Brightness, as many assume. The unit of measure for luminous intensity is the candela (cd). One candela, which means *candle* in Latin, is roughly the luminous intensity of one common candle. The preferred system of measure is expressed as candelas per square meter ( $\text{cd}/\text{m}^2$ ).

As with most standards of measures, there is another luminance unit. The foot-Lambert (fL) is the US/English unit of luminance. A fL can be converted (rounded) from candelas with the following formula:  $1 \text{ fL} = 3.7 \text{ cd}/\text{m}^2$ . The fL used to be used by the motion picture industry to express the luminance of images on a projection screen; it is still in use in the flight-simulation industry as a measurement of its visual display systems.

The maximum luminance capacity of an LCD display is determined by the backlight system. This can be either a Cold-Cathode Fluorescent (CCF) or Light Emitting Diode (LED) system.

*A key difference between medical and commercial displays is that medical displays have a closed-loop control circuit to maintain a stable peak luminance from a cold start to thermal stability (when fully warmed up).*

CCF technology could take as much as 2 hours to stabilize from a cold start. This correction requires a precision photometer mounted near the input source on the back of the display to monitor the luminance output. The actual output is compared to the desired peak value and a corrective signal is generated for the control circuit. This is all done automatically in the background, many times per second.

Commercial displays have a control circuit with a variable input selection, unfortunately called a *brightness control* by some vendors. It may have five to seven steps or provide a smooth variability over a predetermined range. There is no reference to an absolute luminance value associated with the setting.

Note: CCF lamps cannot be dimmed down like an incandescent lamp; they have a minimum threshold to function. The absence of closed-loop control and a photometer is the cause of drift over time (cold to hot on start up) and the absence of any correction as the CCF lamps (or LED) age from use.

*The lack of quality control capabilities with most commercial-grade monitors will require frequent calibration checks to maintain a close approximation to the desired peak luminance.*

- **Contrast/brightness**

Contrast on a display is the range of luminance available from an “off” pixel to a “100% on” pixel; the off pixel does not mean a total absence of luminance. Luminance Ratio, LR, (the old terminology is *Contrast Ratio*, CR) is calculated by dividing the minimum luminance into the maximum as measured with a full screen driven at the respective values. For example: An  $L_{\min}$  of  $1 \text{ cd/m}^2$  and  $L_{\max}$  of  $450 \text{ cd/m}^2$  would yield an LR of 450:1.

However, this does not include two factors that influence the resultant image quality. Adjacent pixels at min and max luminance values do not produce a 100% contrast difference (modulation). In addition, luminance from the max pixel influences the min pixel as perceived by the eye, and this simple calculation does not include ambient light contributions.

*A medical-grade 3-MP LCD monochrome monitor should be able to produce a contrast modulation of approximately 93% between an “off” vs. “on” pixel.*

As a reference, the venerable CRT just barely produced 60% contrast modulation at screen center. This measurement also fell precipitously at the corners of the display. Color CRT’s had

even worse contrast modulation, although color LCD's can perform at the same level as monochrome LCD's.

- **Ambient light**

One of the major display issues is the contribution of ambient light, especially in bright areas such as the ER or ICU. Not taking this factor into account impacts the capability to see pathology in the black area of the display. Ambient light comes from many directions as indirect light sources; the proper terminology is *diffuse light*. This adds to the minimum luminance perceived, in much the same way as a rising tide equally lifts all boats.

A display pixel that provides a Presentation Value (also known as a *P-Value* in DICOM viewer software) that represents a luminance value less than the ambient light contribution will not be observed; it is effectively washed out by ambient light.

The first P-Value that exceeds the ambient light by a luminance value detectable by the viewer is where the black level needs to be (zero P-Value). The Minimum Luminance, or  $L_{min}$ , should be 1.5 times the measured ambient light as a minimum correction<sup>1</sup>; the ideal correction is 4 times the ambient contribution.

*If the screen has a combination of light leakage and an ambient light contribution of 1 cd/m<sup>2</sup>, the black level (where the digital driving level [DDL] from the graphic card is zero) needs to be 1.5 cd/m<sup>2</sup> or ideally 4 cd/m<sup>2</sup>.*

How do we make sure the ambient light can be measured with a light meter? With the display turned “off” so that only ambient light reflections (illuminance) are present, hold the meter's pod approximately three inches from screen center and take a reading. If other areas appear to have more reflected light than screen center, measure nine separate points on the display—in a 3x3 array—and utilize the highest reading. A reading room with proper lighting should not cause “hot spots” of ambient light on any display. Using the Quality Control (QC) software's calibration function provided by the display vendor, set the DDL to zero and adjust the luminance level between 1.5x and 4x the measured ambient.

- **Contrast sensitivity, threshold and adaptation**

Contrast sensitivity characterizes the sensitivity of the “average” human observer to luminance on a Standard Target (DICOM Standard Definition<sup>2</sup>), or, more simply stated: Whether or not an observer can see differences between different gray levels, such as a nodule in a chest X-ray. The Standard Target mentioned by DICOM is a test pattern of alternating bars,  $\pm$  luminance to the background. They are defined for scientific measurements of the Human Visual System

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<sup>1</sup> AAPM [OR 3 document](#), page 121, Table 7

<sup>2</sup> DICOM Standard [PS 3.14-2009](#)

(HVS) to keep things consistent—to the extent possible with a wide cross-section of observers. The observer's ability to see the bars is his or her sensitivity.

The contrast threshold defines the luminance differential required for the observer to detect a difference. The DICOM GSDF is a table of luminance values separated by the average observer's ability to detect a Just Noticeable Difference (JND). For displays, this table starts at JND 1, equal to  $0.05 \text{ cd/m}^2$ , and ends at JND 1,023, equal to  $3995.4040 \text{ cd/m}^2$ .

For the typical observer, each JND step is the contrast threshold of the human eye. Some observers can detect smaller changes while older eyes will require a larger contrast difference before a JND is discerned. A typed page of text is the gold standard for contrast. When read in appropriate lighting conditions, it represents 100% contrast modulation.

*Sensitivity and Threshold are an inverse relationship. The smaller the object, the greater the contrast difference required to make it stand out. That is why zooming an image is critical.*

Adaptation has a significant influence on the ability to detect any differences or JNDs. A high average scene luminance makes it difficult to detect details in dark areas. The term *Contrast Threshold* plots the JNDs divided by the luminance across the Luminance Range (DICOM Standard Definitions). This is the plot that typically shows up on a slide presentation to explain GSDF calibration protocol. The fundamental problem is that the low end of the GSDF table of luminance values defining JND steps is observable as long as the eye is adapted to low luminance. If the adaptation level is at the high end of the GSDF table, a one JND step at the low end cannot be detected.

The ability to detect a one JND step decreases above and below the point of scene adaptation on medical images (average scene luminance). At a given adaptation, the eye has a dynamic range of 250:1. A chest image average scene luminance is approximately  $50 \text{ cd/m}^2$ , which means the detection of JNDs at the extremes of luminance need to exceed one JND3, otherwise you cannot see a one JND step change and could potentially miss information.

Adaptation includes the environment the radiologist came in from before sitting down to read. Prolonged presence in a bright ER or office area (or even driving in a car without sun glasses) will make it difficult to read in dark regions of interest until the eye has adapted.

*Radiologists should always make sure their eyes are adapted before making any primary diagnosis for 15-30 minutes.*

## Display format

The display format (**not** resolution) is the physical structure that defines the number of pixels and diagonal screen size; both values define the “active video area.” Two basic configurations exist, from old to new: Standard Definition (SD, 4:3) and High Definition (HD, 16:9). These terms, SD or HS, describe only the aspect ratio of the horizontal to vertical mechanical measurement. Pixel density, such as 2560 x 2048 (5 MP), within a given physical area determines the pixel pitch, the actual size of an individual pixel (for 5 MP the pitch is 0.165 mm). This, again, is not resolution; the capability to *resolve* one pixel from another is resolution.

Monochrome and color can also be considered part of the format criteria. This does not alter the pixel pitch. A monochrome display of 3 MP has a pitch of 0.207 mm and it contains three equal sub-pixels. Within the same space, a color 3 MP has the same sub-pixels but with color filters applied: Red, Green, and Blue (RGB).

*Color is less efficient—by approximately 50%—for passing luminance energy through the Liquid Crystal material using the same backlighting system. Therefore, color displays require a higher maximum luminance compared with monochrome displays.*

## Spatial resolution

Spatial resolution<sup>4</sup> is the quantitative measure of the capability of a display system to produce separable images of different points of an object with high fidelity. Systems designed with adequate spatial resolution characteristics are necessary to assure that spatial details of interest (the source) are preserved onto the display.

*Rendering image data onto a display with insufficient resolution, such as when displaying a 5-MP image on a 3-MP display, will compromise the accuracy of the radiological interpretation.*

The effective resolution of a display was a critical issue with CRT-based displays because of how that technology generates pixels. A 5-MP CRT cannot produce distinguishable pixels at 100% modulation (the differential of an on-off-on pixel pattern). The same CRT display lowered to 3-MP format improved the modulation, but it is still short of 100%. LCD displays at a 3-MP format (a pixel pitch of 0.206 mm) can achieve 93% modulation over the entire screen area, hence the major advantage of this technology over CRT's.

The inverse relationship of Sensitivity and Threshold Modulation means that as an object of interest becomes smaller, the greater the luminance difference to the surround must be for detection. The opposite is also true, i.e. the larger the object the less the luminance difference required. A single micro calcification rendered by a single pixel will need to be more

<sup>4</sup> [AAPM OR 3](#); Page 95; Paragraph 4.5.1 Description of Display Resolution

than one JND above the surround to be detected, but if it were rendered by 9 or 16 pixels (retaining the aspect ratio) it would require a lower differential of JND's.

If the same micro calcification was detected by a single element on a digital capture (FFDM) device of 50 microns spatial resolution and the image needed to be magnified so that it was mapped to a single display pixel of 165 microns (5MP), then the display's spatial resolution is less than the captured image. If the observer is unable to detect it at the luminance rendered, then one of two things must happen. Either one can further magnify the object so it is large enough to be detected at the current luminance differential, or increase the dynamic luminance range of the display so that the DDL has a larger JND step size, i.e., the micro calcification becomes brighter relative to the surround.

Lack of spatial resolution can be compensated by zooming an image; however, this will impact the productivity and workflow of the observer.

### Color temperature

The color temperature defines the net appearance detected by the eye of the backlights on a monochrome display, or the balance between the RGB sub-pixels of a color display. CCF backlights utilize a phosphor similar to P45 (a standard medical and photographic phosphor used in CRT's) that emits three distinct energy peaks at the Red, Green, and Blue wave length. A monochrome display can appear like pure white (7200° Kelvin) or more bluish (at 10,000° to 12,000° Kelvin). Blue content improves the contrast detection of the eye. Note that Kodak blue-base film is close to 10,000° Kelvin for comparison. Vendors can offer white or blue CCF lamps for some LCD-core sizes; the white lamps at 8,000° Kelvin have sufficient blue content to aid in contrast detection.

Color temperature to a physicist is the emitted light energy of a black body when heated. Saying steel is white hot or red hot is based in science—not urban legend. The color temperature for medical soft copy is intended to mimic the appearance of x-ray film from neutral density to Kodak blue base, which is relative to the CCF lamp offerings of *White* and *Blue*. The choice is a personal preference and tends to be influenced by past film experience for the older generation of radiologists.

Monitors are typically matched with regard to their color temperature. This is also dependent on the manufacturing batch of the CCF lamps. This becomes especially apparent when having to replace one display out of a matched set of two.

*Except for esthetics and personal preferences, color differences should not impact any diagnostic capability.*

## LIGHT BOX vs. MEDICAL DISPLAY

Although the light box is considered by many imaging professionals as the gold standard, it is film that is the actual gold standard (with film rendering between 8 and 20 line pairs/mm [lp/mm] for chest or mammography film, respectively). A 5-MP LCD mammography display has 0.165 mm pixels, which equals 3 lp/mm, and a 3-MP display at 0.206mm pixel equals 2.5 lp/mm. That represents a significant difference between a film and LCD in image detail per unit of viewing area.

Light boxes that were well maintained have luminance variations (if no film present) of 30%, while poorly maintained boxes could have variations as high as 50% between measured points. Putting a new fluorescent lamp in with old ones that have aged naturally is a variation very visible to the eye, when viewed approximately six feet away from the source.

However, when film is hung and viewed from arm's length, the variations are not visible. At six feet the sinusoidal variation caused by a new lamp is within the eye fovea's detection area, but at a reading distance of 18-26 inches, coupled with the luminance attenuation of the film, the uniformity of the light box is non-germane. Non-uniformity of the light source cannot be detected.

*The same principle applies to the LCD display: At a normal reading distance for viewing an image, the non-uniformity of the display, such as that caused by a different lamp output, is not generally noticeable.*

Light boxes require manual magnification, i.e., a radiologist moves their eyes closer to the film. Film with a high optical density requires a hot light to increase the intensity so that subtle details may be visible within the darkest regions. Very bright areas of film (eye adaptation) mask darker details that can be pulled out by covering the bright area with a black masking material.

The procedures to deal with light box/film shortcomings are handled in the digital world with software tools, such as magnification, Window/Level, Inversion (polarity), and custom corrections for specific anatomy (known as Look-up-Tables or LUTs). Magnification (pan and zoom) allows the image to achieve a 1:1 ratio with the captured image when the image originates from a higher spatial-content source than the display can render.

*Low spatial images such as MRI/CT (256 x 256 pixels as captured) fit well on a 2-MP display at 1:1, but suffer on a finer pixel-pitch display—such as three or more megapixels—due to the need for extra magnification to bring the physical size back to the equal of a 2 MP.*

Hot light and masking tools equate to Window/Level tools. A high optical density (OD) image (high dynamic-range digital image) with a digital depth of 14-16 bits/pixel is scaled to 8-bits (P-Values) for the video graphic card/display. The 8-bits cannot display all the details of 14-16 bit image sources, so a window is selected from the source image. The window can be very narrow, only a few bits wide scaled to 8-bits, to amplify the contrast detail.

*Selecting 8-bits (sequential) as the window width (having a value of 256) provides a 1:1 capture-to-presentation state on a monitor. Therefore, using less than 8 bits, i.e. a window of less than 256, only causes a digital magnification so that pixel values (in absolute luminance) are separated by JND step sizes of one or greater.*

This still represents an improvement because the display has a much smaller dynamic range than film or a 16-bit image, and pulling an area of interest out as a window allows the display to render the fine details that may otherwise not be detectable.

Using a mouse click to invert an image is obviously not possible with film. Optimizing a data set for a specific anatomical region is also not the realm of film without a retake, and fixing an exposure by shifting the data set to avoid retakes is also unique to digital capture. Probably the best perk of digital imaging is the capability to send it anywhere in minutes for a second read.

## **COLOR vs MONOCHROME DISPLAY**

Color vs. monochrome was not an issue when digital soft copy was first on the scene. Color was relegated to ultrasound (after it also started out as monochrome). Color for nuclear medicine images, even a CRT, was more than adequate due to the low-spatial content of the image. The advancements that have occurred with image capture, along with software enhancements, have brought color to the forefront. A volume of monochrome data taken by CT/MRI can be processed into a pseudo-3D image with texture, color, and a realistic appearance. But can the color display render a chest image (CR/DR) without compromising the image quality associated with a monochrome display?

*A color will perform the same as a monochrome display as long as all the performance issues of the displays are equal and at or above AAPM minimums for peak luminance, luminance ratio, and  $L_{min}$  for ambient light.*

Spatial resolution must be adequate for the image source to show fine edge details while still being able to resolve JND's of adjacent pixels. The physical difference is color filters; otherwise the technology of color vs. monochrome has few differences within an LCD display. They share the same backlight system-aside from the color display therefore requiring more lamp output to match a monochrome's peak luminance.

The filters separate the three primary colors of the backlight and control them with their respective sub-pixel (RGB). The balance of the RGB filters to produce a white screen is 70% green, 20% red, and 10% blue. Three distinct color cones in the eye detect the green, red, and blue wavelength—with the green cones being the most sensitive.

Because the eye detects distinct primary colors, the image presented by a monochrome display is actually being detected in the same way as color. The only difference is how they are controlled. The monochrome LCD passes them through the three sub-pixels as a combined spectrum; the color LCD separates them and either balances the RGB for a film appearance or to make a Kodak moment.

*If a 3-MP monochrome LCD was utilized for x-ray (screen/film) type images, then a 3-MP color LCD operating at equal performance levels will render the same image quality.*

The key to optimizing the image still falls back to selecting a display format with the proper spatial resolution to render the source image details without excessive need for pan/zoom tools, which lowers the efficiency of the reader; but it does not alter the accuracy or confidence level of the reader.

## **WHAT IS THE OPTIMAL DISPLAY FORMAT TO USE?**

The decision matrix for determining which display format to use is driven by the modalities being rendered. There is one fixed, non-negotiable modality per the U.S. FDA: All mammography images must be displayed on a 5-MP monochrome monitor that has a cleared 510K filing with the FDA, which specifies that its use is intended specifically for mammography. This is distinct and separate from a general radiology 510K listing that can include a complete product line of displays as a group. The testing, and proof thereof, is substantially different for the mammography 510K listing.

Again, spatial content vs. display capability is key; mammography film at 18-20 lp/mm is substantially greater than the 3 lp/mm of a 5-MP display. Digital tools are key to seeing all the details.

Imaging modalities are technical wonders in and of themselves, but they do represent a broad spectrum of image detail based on line count, the native format generated by the modality. For example, Intravascular Ultrasound (IVUS) has approximately 126 lines of data from a transducer on the end of a catheter. Cross-sectional MRI/CT yields square slices at 256 x 256 pixels for an optimal signal-to-noise (SN) ratio or 512-square pixel slices. CR/DR modalities range between 50 to 150 microns at capture, or a derived effective equivalent. A film scanner has similar

spatial resolution for general radiology and mammography digitizing. See table 1 for the recommendations per modality.

Modality Capture (Microns)	Modality Matrix as captured	Screen Size (Inches)	Screen Pixel Matrix	Color Required for:	Comments
Ultrasound IVUS	512, 768 & 1024 126 lines	18 to 19 15 to 18	$\geq 1280 \times 1024$ $\leq 1280 \times 1024$	Doppler	IVUS, avoid screen sizes above 18" diagonal
NUC/PET PET/CT	Variable	18 to 19 19 to 20.1	$\geq 1280 \times 1024$ $\geq 1600 \times 1200$	Encoding	Not recommended on 5 MP Pixel size: $\geq 0.206\text{mm}$
MRI/CT ~ 1mm/Slice Typical	256 & 512	19 to 20.8	$\leq 1536 \times 2048$	Enhanced 3D Re- Construction	Not recommended on 5MP Large studies on 4 MP 30" diagonal color. Pixel $\geq 0.206\text{mm}$
fMRI	256 & 512	19 to 20.8	$\leq 1536 \times 2048$	Contrast Enhancement	$\leq 3$ MP color or monochrome or 6MP @ $\geq 0.206\text{mm}$
Fluoro/R&F CT- Fluoro	1024 x 1024	18 to 20.1	$\leq 1600 \times 1200$	N/A	1280 x 1024 minimum for 1:1 aspect image w/in 5:4 screen. Gray-to-Gray cycle response time $\leq 13\text{ms}$
CR/DR (100- 150)	4 MP	20.8 to 21.3	$\geq 1536 \times 2048$	N/A	Ideal fit to 3 MP, color or monochrome $\geq 400 \text{ cd./m}^2$
Digitized Film (50-150)	8 MP ~ 8-10 lp/mm	20.8 to 21.3	$\geq 1536 \times 2048$	N/A	3 MP color or monochrome 5 MP monochrome
Mammography (50-100)	20MP+ ~ 18-20 lp/mm	21.3	2048 x 2560	N/A	FDA requires 510K approval specifically for Mammography

*Table 1 recommended monitor specifications per modality*

*One size of monitor clearly does not fit all modalities.*

The following examples illustrate our point:

When IVUS was first introduced as a product, the display size was a color 15" LCD with a peak luminance indicative of a commercial LCD at 250 to 280  $\text{cd./m}^2$ ; XGA format (1024 x 768); and a pitch of 0.297 mm. Within the 15" diagonal screen (9 x 12 inch/304 x 228 mm, active video), the circular image of the interior of a vessel at 126 lines is expanded to approximately 380 lines, a 3x magnification as a starting point. The boundary of the vessel wall is rendered as a black annular ring with cell structure and/or foreign material within (plaque). The contrast of the annular ring to the white cells is well defined because the pixel pitch (0.297 mm) provides a very resolvable image at reading distance and luminance ratio of 250:1 in typical reading conditions. Moving to a larger screen of 19" diagonal (14.8 x 11.9 inch/376 x 301 mm), a brighter luminance range of 350  $\text{cd./m}^2$ , and a pixel pitch of 0.295 mm on 1280 x 1024 (SXGA) format, the net result is to reduce the impression of the black annular rings (the adaptive point is now higher) and defining edge details. When an image starts at 126 lines (captured) and must be expanded to fill the desired space, the new pixels are a calculation that must maintain the aspect ratio of the overall image while not corrupting the sharp-edge detail. Vertical and

horizontal lines are easy, but diagonal lines and circles get messy. Magnification leads to pixelization, and the move from 768 lines to 1024 (approximately 50% of the lines available), crosses the threshold of good to bad for IVUS.

*More is not always better, and as a point in case, can be worse.*

Another example is found in the desire to save money and implement a one-display-format-works-for-all-modalities scheme.

If mammography is the highest spatial image, 5 MP is required. But is that appropriate for CT/MRI? The display can certainly handle the cross-sectional images, but what happens to it on a pixel pitch of 0.165 mm compared with a 2-MP display at 0.250 mm? The transition is going to look like thumbnail images. The first action is to enlarge the image to a more familiar size to see the dynamic range of CT/MRI. The smaller the object, the greater the contrast has to be for detection of a difference.

*Cross-sectional images are best served by 2- and 3-MP displays; 3 MP is the optimal format for reading comfort.*

## CONCLUSION

A medical professional should be looking at a medical-grade diagnostic display for any image for the purpose of providing care, whether labeled as diagnostic or emergency life saving procedure--and nothing less. That does not imply it has to be an FDA-listed display product in every instance, but it does mean that it has to have minimum standards of performance as noted by the AAPM and DICOM Part 14 GSDF.

The FDA requires a 5-MP display for mammography; there should be no exceptions to this requirement, unless the imaging source (modality) is something other than Full-Field Digital Mammography (FFDM) or digitized film from a conventional film-screen mammogram.

MRI, IVUS, CT, and the next advancements that comes from lower spatial content can be viewed on lower spatial resolution displays—color is not an exception; it should also provide the same image fidelity as monochrome.

General radiology displays need to mimic the spatial resolution of the source as close as possible while meeting the minimum performance references noted above. Low spatial sources, such as CT/MRI, work well on 2-MP displays or the equivalent by pixel pitch in larger formats such as 4-MP, 30" diagonal. Ultrasound works on 1.3-MP and 2-MP COTS for applications that fall below critical care, such as breast imaging. The majority of general radiology images are best viewed on a 3-MP display, based on reading distance and pixel pitch for optimum detection.

In every situation, the consistency of images throughout a facility is as important as their creation. Only when the display of a diagnostic medical image has been optimized for the modality that generated it can the HVS can detect the smallest object of diagnostic import.

## About the Authors

**Ken Compton** has been involved with medical display technology for most of his career. Mr. Compton has worked for several of the major medical-grade display vendors such as Clinton and NDS surgical. He participated in the AAPM task group 18 and was co-author of its document for medical displays. Mr. Compton is the author of a handbook on medical displays. He is currently president of Dallas-based Medical QC Images, a medical image quality consulting firm. Mr. Compton can be contacted at [kdcompton@aol.com](mailto:kdcompton@aol.com)

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