MONITOR IMAGE QUALITY ASSURANCE AT THE UNIVERSITY HEALTH NETWORK

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Introduction

Although the high quality of medical images is strictly controlled during acquisition, it is often not adequately maintained during image review. This is due to the lack of a published process and information on optimal monitor settings for medical image viewing. Other complications include large differences between various types, applications, and vendors[1], and scarce literature describing monitor quality control protocols[2]. Guidelines and recommendations also vary between countries and are sometimes conflicting[3, 4].

The University Health Network (UHN) is comprised of the Toronto General, Toronto Western, and Princess Margaret Hospitals. The UHN Medical Imaging Department also manages medical imaging at the Mount Sinai Hospital (MSH). Approximately 450 computers at UHN and 200 computers at Mount Sinai Hospital are able to review medical images through the PACS (Picture Archiving and Communication System) using the eFilm[5] Workstation application. The majority of PACS clinical review workstations are located in clinics and physicians' offices. A smaller number of the PACS workstations are used by radiologists in reading rooms. The PACS monitors are heterogeneous with respect to manufacturer, type (CRT versus LCD, colour versus greyscale, etc.), age, size, and image quality. This initiative is the first comprehensive monitor quality assurance program at UHN and MSH.

Hypothesis

The regular calibration of PACS monitors will maintain image quality.

Methods

A monitor image quality protocol was developed using published guidelines, other hospital monitor calibration methods, and experiences from past image quality issues at UHN and MSH[2, 4, 6, 7]. The calibration reporting sheet currently being used is shown in Appendix A. Minimum requirements that UHN and MSH PACS monitors should meet were drafted for different categories of PACS monitors. A subset of the recommendations is given in Appendix B.

The protocol encompasses cleaning the screen, setting the appropriate maximum luminance and dark level, gamma calibration to the DICOM standard, and visual checks for sharpness and other potential artifacts. A commercial calibration kit (VeriLUM by Image-Smiths Inc.) was used to measure luminance values and to calibrate the monitors to the DICOM standard. The VeriLUM kit includes a SMPTE (Society of Motion Picture and Television Engineers) pattern used for visual checks (Figure 1). This kit was chosen because it can calibrate a number of different brands and types of monitors with various graphics cards.

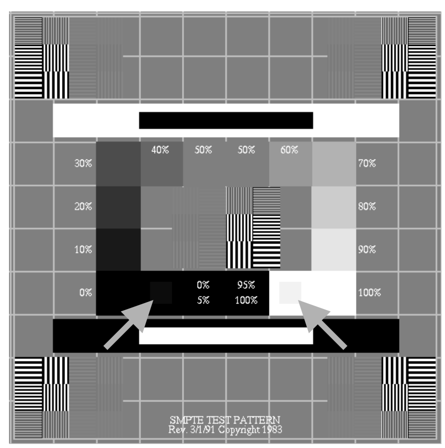

***Figure 1**. SMPTE Pattern: Left arrow indicates a* 5% luminance square inside a larger 0% luminance square. Right arrow indicates a 95% luminance square inside a larger 100% luminance square.

A variety of clinical and radiological PACS workstations were identified for use as a pilot for the protocol. The motivation behind the pilot included: 1) to determine the value of a monitor quality control program by assessing the current state and noting any improvements after calibration, 2) to validate and if necessary, to modify the protocol, and 3) to determine the time required to calibrate the PACS monitors.

Sixteen PACS workstations (11 dual monitor systems and 5 single monitor systems) have so far been calibrated for the pilot. Three of the workstations were included for the pilot due to poor image quality complaints, while the other workstations were randomly chosen from the Medical Imaging Department and clinics to represent a range of monitor types.

Results

Four workstations had monitors that were found to produce images of too low quality for PACS applications even after calibration. Subsequent to calibration, two of the workstations have had monitors replaced because of blurriness and inadequate luminance. The calibration photometer was not able to connect to two non-standard UHN workstations, both of which had monitor quality deemed inadequate for medical image viewing, and have been excluded from the following results summary.

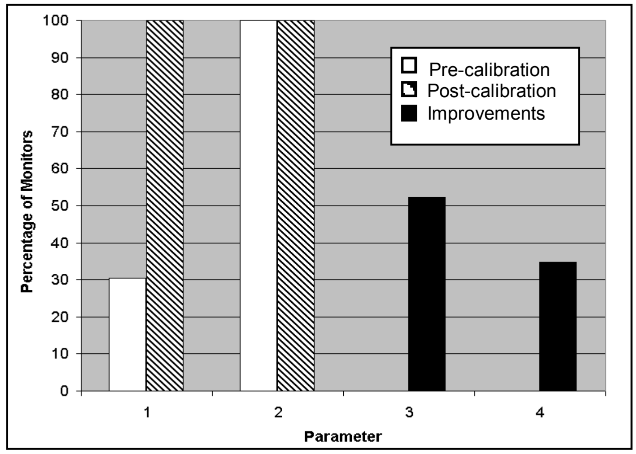

Figure 2. Image quality improvements through calibration
1. *Monitors able to discern between 0% and 5% luminance values*
2. *Monitors able to discern between 95% and 100% luminance values*
3. *Monitors with max. luminance not optimally set (difference between calibrated and original values >10 cd/m^2)*
4. *Monitors with dark levels not optimally set (difference between calibrated and original values >0.2 cd/m^2)*

Most monitors showed significant image quality improvements from calibration (Figure 2). Prior to calibration to the DICOM curve, on the majority of the monitors, the difference between 0% and 5% luminance could not be seen on the SMPTE pattern. After calibration, this difference was discernible on all the monitors. The maximum luminance and dark levels were often adjusted to prolong longevity of the monitors while trying to optimize image quality. Other image quality degrading factors that were found include blurriness, the hospital logo burned onto the screen, incorrectly set aspect ratios, and dirty screens.

For someone with training but little experience with monitor calibration, it took on average 30 minutes to calibrate one monitor.

Discussion

It is clear that calibration and periodic testing of PACS monitors is an important step for assurance of image quality. Clinical reporting is often delayed until there is advanced image degradation. Properly calibrating a monitor can potentially help prolong the lifecycle by setting the optimal luminance for both image quality and monitor longevity. A quality assurance program may produce data regarding the useful lifecycle of different monitors.

The frequency of calibration is highly variable. Some institutions perform weekly monitor tests, while some never calibrate monitors. At UHN, the workload associated with ongoing testing would likely require a dedicated full-time technician.

There are other important factors besides monitor calibration that can facilitate the maintenance of image quality. UHN is in the process of streamlining the escalation procedure of PACS equipment issues, which is necessary because of the large size of the institution and the overlapping responsibilities between groups. A database is also being created to report calibration results, age, warranty, location, etc. of the PACS monitors. Disabling user control of the contrast and brightness settings, and training the users to modify the window and leveling settings instead in the PACS viewer application, will help maintain a properly calibrated monitor. Environmental factors, such as ambient lighting, glare, and placement of the monitor at eyelevel, should also be considered for optimizing medical image viewing[8, 9]. Standardizing on PACS hardware, or at least reducing the number of different brands, can assist in the development of maintenance and leasing arrangements.

As monitor technology advances and quality assurance regulations mature, more hospitals will likely adopt more aggressive image quality programs. Monitors are now available that periodically do selfcalibration, and many of them come factory calibrated. Unfortunately, these are usually very expensive high-end monitors[10]. Remote calibration is also becoming more feasible, but it could be prohibitively costly to standardize onto one high-end monitor brand.

Is there any data supporting the clinical relevance of your testing parameters? If not this should be speculated and cited as an area for future research

Conclusion

It has been shown through the pilot of a monitor quality assurance protocol that a proactive calibration program is necessary to ensure adequate image quality. A working monitor calibration protocol was tailored for the monitors and graphics cards used at UHN. Substantial image quality improvements were seen, and a systematic and quantitative method of determining the appropriateness of a monitor for PACS was developed. The protocol will continually be updated and modified with the advancement of monitor technology, as more information is gathered concerning optimal PACS monitor parameters, and as further recommendations and laws come to pass.

Appendix A: Reporting Sheet for Monitor Calibration Data

Person Performing Test: ______________________ **Date:** _____________________
Reason for Calibration: ____
Department: _________________________
Location: _________________________
Monitor Type: ________________________ **Asset Tag:** _________________
Single Dual **Age of Monitor:** _____________
Color Greyscale
CRT LCD
Computer Type: _______________________ **Asset Tag:** _________________
Graphics Card Type: ___________________
Calibration Kit: (Specify if other than Verilum) __________________
Resolution Setting: _______________________

Maintenance/Test	Monitor 1		Monitor 2		Notes
	Previous Measurement	**Calibrated Measurement**	**Previous Measurement**	**Calibrated Measurement**	
Cleaning -wiping monitor					
Pre-calibration SMPTE pattern check 95%-100% discernible? 0%-5% discernible? Bar pattern/font clear?					
Black Level -adjust brightness knob to 0.2-0.5 cd/m2					
Max. Luminance -adjust contrast knob to ideally over 170 cd/m2 for diagnostic monitors					
Closed-loop calibration -can verify with “Track” option					
Uniformity -visual check probably sufficient with LCD monitors					
Post-calibration SMPTE pattern check					

95%-100% discernible?					
0%-5% discernible?					
Bar pattern/font clear?					
Entire field of view**?**					
Adjust **geometry** if necessary					

Total time required for testing: ____________________
Comments (eg other artifacts observed)**:**

Appendix B: Subset of Proposed Minimum Requirements for Adequate Monitor Image Quality

	Clinical			**Radiological**		
Parameter	**Clinical Review (Colour CRT)**	**Greyscale (CR/DR)**	**Colour LCD**	**Greyscale (CR/DR)**	**Colour (CRT/LCD)**	**Greyscale (not for CR/DR)**
Max. Luminance (cd/m^2)	>100	170	>100	250	>100	170
Dark Level (cd/m^2)	CRT: 0.2; LCD: 0.5					
Gamma Calibration	Yes	Yes	Recommend	Yes	Yes	Yes
Uniform Luminance	<25%	<25%	<25%	<25%	<25%	<25%

CRT: Cathode Ray Tube; LCD: Liquid Crystal Display; CR: Computed Radiography; DR: Direct Radiography

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