Frequency and Impact of High-Resolution Monitor Failure in a Filmless Imaging Department

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The purpose of this study was to assess the image quality and the rate of failure of the high-resolution (2,048 × 1536 pixel) monitors used for primary diagnosis in a filmless radiology department and to analyze the type of problems encountered as well as the action taken to repair the monitors. Data were collected from Picture Archival and Communication System (PACS) service logs to determine rates of monitor adjustment and replacement, the symptoms reported, and the action taken. Additionally, random surveys of the high-resolution monitors were performed using a standard test pattern to assess spatial and contrast resolution in the center and outer corners of the monitors. Analysis of monitor service records showed a high rate of monitor replacement (41% per year) resulting in a relatively short "life expectancy" (defined as average time required before replacement) of 2.4 years. Random surveys of monitor quality using a standard test pattern showed suboptimal image quality in approximately 54% of the monitors with moderate image quality degradation present in at least one region of 27% of the high-resolution monitors, despite our vendor's quality control program. The results of this study support our subjective impression and those of other colleagues in the PACS community of an unacceptably high monitor failure rate and persistent image quality problems with 2,000 pixel monitors used for primary diagnosis. The relatively high incidence of suboptimal quality monitors suggests that more frequent quality control should be performed using a test pattern particularly given the fact that radiologists often are unable to discern degradation of monitor performance using clinical images. The high incidence of problems with image quality on high-resolution monitors indicates that vendors need to develop better quality control in monitor design and testing. Radiologists should review briefly a test pattern on each monitor at the beginning of each day. A computer program should be incorporated into the PACS, which asks radiologists to evaluate a test pattern and records the results in a central database, which is communicated to the service engineers. Further studies should be evaluated to determine the clinical impact of monitor image degradation, which is relatively easily seen using a test pattern but may be difficult to discern on clinical images. Requests for proposals (RFPs) for PACS and service contracts must

specify carefully requirements for monitor image quality and conditions under which the vendor is required to replace these monitors.

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THE IMPORTANCE of quality control and details of implementation of such a program for high-resolution monitors utilized for primary diagnosis with a picture archival and communication system (PACS) have been the subject of a number of reports in the literature.¹⁻⁹ We are, however, unaware of any previous reports of actual clinical experience with the nature of problems with image display and failure rates of monitors and video cards.

Anecdotal reports from other facilities in addition to our own experience have suggested that the failure rate of high-resolution monitors has been unacceptably high. Our initial experience in 1993 (before service logs are available from our current vendor) was that there was an initial (ie, within 1 month of delivery) failure rate of the high-resolution monitors of approximately 20% with an average monitor life expectancy of less than 1 year. Additionally, there were a large number of reported problems with image quality and wide variability of brightness from monitor to monitor and for a single monitor over time.

The purpose of this study was to assess the image quality of the high-resolution monitors utilized for primary diagnosis in the radiology department, to analyze the reported problems with image display, and to determine the frequency of monitor repair and replacement.

MATERIALS AND METHODS

Our research assistant was provided with an overview of the study design and underwent 2 training sessions in the evaluation of monitor quality using a test pattern provided by our PACS vendor. The test image utilized was a SMPTE (Society of Motion Picture and Television Engineers) pattern, stored in the PACS image database and optimized for display on the high-resolution monitors. This test pattern was used to determine both

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contrast and spatial resolution of the monitors used for primary diagnosis in the radiology department. A survey was made of the high-resolution (2048×1536 pixels) monitors in the radiology department. The observer determined, for each monitor, whether the 5% signal level steps at both ends of the gray scale were visible as suggested by Gray.¹⁰ Image distortion and resolution were assessed by determining the ability to visualize the horizontal and vertically oriented closely spaced line pairs in the 4 corners and center of the SMPTE pattern and were rated on a scale of 1 to 5. A score of 5 was assigned to a corner or center of the pattern in which the lines were sharp and easily discernable without blurring or other image distortion. A score of 4 was assigned to areas in which a definitely noticeable distortion was present, and a score of 3 was assigned to areas of moderate distortion. A score of 2 was reserved for cases in which the portion of the image was unreadable, and a score of 1 was to be assigned to portions of the pattern in which no detail was discernable. A quadrant or center of the monitor rated as a 4 was considered to be marginally or questionably acceptable, and any monitor with a portion rated at a 3 or below was considered unacceptable for clinical use. These data were entered into a spreadsheet and were analyzed.

To assess the frequency and nature of image display and monitor failure, the maintenance records (for the 2048×1536 pixel monitors only) of our vendor were reviewed. The interval during which the records were reviewed consisted of 6 months in 1997 and the first 11 months in 1998. The maintenance records in which a major problem was reported with image display on a high-resolution monitor were listed. For each of these entries, the date on which the problem was reported, the nature of the problem, and the action taken to correct the problem including replacement of the monitor were noted. This information was entered into a spreadsheet for analysis.

Our PACS vendor utilizes a monitor test and calibration procedure that is performed on a quarterly basis. The service manual specifies that the technicians test and calibrate the width and the height of the image, test for linearity of horizontal and vertical straight lines, adjust overall luminance and black levels, and test for luminance uniformity as well as testing contrast and brightness. The service technicians are able to make limited "fine" adjustments for the center of the monitor but are not able to focus selectively the edges of the image. The test for contrast is performed by verifying that the 5% block on the SMPTE pattern can be seen at the center of the 0% block, and the 95% block can be seen in the center of the 100% block. This assessment essentially is the same that was performed by our research assistant. The vendor's testing and calibration procedure does not include specifically an assessment of the horizontal and vertical bars in the corners and center of the SMPTE pattern.

RESULTS

Review of Vendor Maintenance Records

During the 17-month period during which the vendor's monitor maintenance records were reviewed, 20 of the 24 (83%) high-resolution monitors suffered a major hardware failure. This repre-

sents a failure rate of approximately 5% per month (59% per year) with an average time until a major repair of 1.7 years. Approximately 41% of the monitors could not be repaired in house by our vendor service technologists and were returned to manufacturer of the monitors for repair. Using this criterion, the average life expectancy of the monitors before they required replacement was approximately 2.4 years.

The most common reason for a monitor service call according to the PACS vendor logs was "no picture," which accounted for 35% of the total (Fig 1). The second most common reason for a monitor service call was low luminescence of a monitor accounting for 22% of the total. Poor image quality accounted for 17%, and a distorted picture was seen in 9%. Miscellaneous causes including "bad smell," "bad switch," "lines projecting over the image," and "partial display of the image" accounted for 17% of the total.

The actions taken by our PACS vendor to repair the monitors also were reviewed. Monitor replacement was required in 61% of the cases (Fig 2). The second most frequent action taken was to fix the monitor video card (22%). Other miscellaneous repairs (17%) included a simple reboot of the computer workstation, repair of the monitor switch, and modifications of the control panel settings.

Assessment of SMPTE Patterns for the Study

All of the high-resolution monitors passed the assessment of whether the 5% signal level steps at both ends of the gray scale were visible. This indicated an acceptable range of contrast for the monitors and indicated that the monitors were set to display their full range of gray scale information.

Fig 1. The most common reasons for monitor service calls were inability to display an image and reduced luminescence that could not be increased without image distortion.

Fig 2. The most common actions taken by our service technicians were monitor replacement and repair of the workstation video card.

The evaluation of linearity, distortion, and resolution, however, showed problems in a number of the monitors in which the entire image or portions of the image were judged to be suboptimal. The average score of all of the quadrants and centers of the monitors was 4.36 out of a total of 5. Of the high-resolution monitors included in the study, only 10 of 22 of the monitors (45%) scored a 5 in all 4 quadrants and the center (Fig 3). Thus, 55% of the monitors were judged to be of suboptimal quality. Additionally, 27% of the monitors had at least 1 area that received a score of 3, which was believed to represent unacceptable quality. Overall, 52% of the 5 areas on each monitor that were rated scored a 5, 33% scored a 4, and 15% scored a 3 (Fig 4).

DISCUSSION

One of the major but unanticipated challenges to early adopters of filmless radiology was the surprisingly poor performance and reliability of high-

Fig 3. Only 45% of monitors scored 5 of 5 in all 5 regions with the majority (55%) of monitors having at least 1 region in which image quality was judged suboptimal or unacceptable. Additionally, 27% of the monitors had at least one region that was scored as unacceptable (3 of 5).

Fig 4. Of the 110 regions evaluated, 52% were judged satisfactory (5 of 5), 33% suboptimal (4 of 5), and 15% unacceptable (3 of 5).

resolution (2,000 pixel) monitors. During the first year of operation of our PACS in 1993, initial monitor failure rates were greater than 20% either at delivery or within 1 month of initial operation. Although we do not have detailed service records from this period, our recollection is that monitor replacement intervals averaged substantially less than 1 year. Initial problems with high-resolution monitors also included an unacceptably rapid and variable amount of "drift" in luminescence resulting in easily perceptible variations in image brightness from one monitor to another. This was particularly bothersome when it occurred among displays in a multimonitor workstation.

Our data show significantly improved but still unsatisfactory performance and reliability of the high-resolution monitors at our facility during the study period despite the vendor's quality assurance program. The average monitor life expectancy has increased somewhat with an average time to replacement of approximately 2.4 years and an average time to major repair of 1.7 years. However, these figures remain well below the anticipated life expectancy of other PACS components including the workstation itself and the PACS server and network, which we estimate will have a useful life expectancy of approximately 5 to 10 years. This short life expectancy suggests that a facility should either include monitor replacement in the service contract, or, alternatively, the facility should ensure that sufficient funds are available for monitor repair and replacement.

The most common image quality problem reported was low luminescence, which reflects the tendency of these monitors to become progressively less bright as they age. Focal spot blooming

limits the amount to which the technicians can compensate for this problem.

Although replacement of the monitor was required in 61% of the cases of major image problems, 22% of image failure or quality problems were related to the workstation video card. Although we are unaware of statistics concerning video card failure on computer workstations in general, this failure rate probably is much higher than with lower resolution video cards. Given the potential loss of productivity with failure of a video card, this relatively high failure rate would seem to mandate a policy in which spare video boards are stored on site.

We were surprised at the high rate of some degree of image distortion seen in at least a portion of the majority (54%) of the monitors tested and particularly in the fact that 27% of the monitors had at least one region with an area of moderate image distortion. This has occurred despite what we believe to be a conscientious quality control program by our vendor. This suggests a greater level (more frequent and more comprehensive) of scrutiny of these workstations, and communication should be contemplated. Interestingly, despite the ability to fine tune the focus of the monitors based on the center of the display, there was no significant difference between the average image quality at the center in comparison with that in the periphery of the monitors.

The relatively high incidence of image quality problems raises the question of their clinical significance. Despite the importance of this topic, we are unaware of any previous report relating improperly set or poor quality monitors to compromise in a radiologist's ability to render an accurate clinical diagnosis. However, we previously have reported decreased radiologist productivity and accuracy and increased fatigue with either decreased monitor luminescence or increased ambient light.^{11,12}

Preliminary data that we have collected for additional studies relating monitor quality and clinical diagnosis have suggested a surprisingly small effect on diagnostic efficacy despite obvious image quality problems shown by review of the SMPTE pattern. Similarly, we have preliminary data suggesting that radiologists are very poor in their ability to use diagnostic images to determine

monitor performance in comparison with the use of a SMPTE pattern.

These findings suggest that a technician, technologist, radiologist, or other health care worker should utilize a test image such as a SMPTE pattern routinely rather than depend on a perceived degradation in image quality, which has been shown to perform poorly in the evaluation of monitor quality. Given the high prevalence of image problems, it is likely that this assessment should be performed on a regular basis such as daily or weekly rather than on a quarterly basis as suggested by the PACS vendor. However, these "obvious" image quality problems discovered on evaluation of the SMPTE pattern may have a relatively minor effect on a radiologist's ability to make an accurate and timely clinical diagnosis. This correlation of a number of monitor image quality problems and their clinical impact is a fascinating topic, which we believe should be studied in much greater detail.

CONCLUSION

Although overall reliability and image quality of high-resolution monitors seems to have improved in comparison with early anecdotal reports, the rate of monitor failure and suboptimal quality continues to be much higher than that of other components of a PACS. Radiologists should briefly review a test pattern on each monitor at the beginning of each day. This could be accomplished using a program incorporated into the PACS workstations that asks radiologists to evaluate a test pattern and records the results in a central database, which then is communicated to the service engineers. Additional work on the development of high-quality, reliable, high-resolution monitors should continue, and alternative technologies such as flat panel imaging systems should continue to be investigated. The high failure rate of our high-resolution monitors may indicate a relatively higher 5- to 10-year cost of ownership than has been estimated initially. These data may be helpful in determining the relative costs and benefits of currently available high-resolution monitors in comparison with these alternative technologies. Requests for proposal (RFPs) for PACS and service contracts must specify carefully requirements for monitor image quality and conditions under which the vendor is required to replace these monitors.

Given the lack of data concerning the clinical impact of suboptimal monitor quality as shown by a test pattern, we believe that much work needs to be done to correlate various monitor deficiencies with clinical diagnostic performance. This work may show the relative clinical importance of various aspects of monitor performance that could

result in new strategies in the development of high-resolution monitors.

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