Guest Editorial: Image Quality Assurance for CRT Display Systems

FOR MORE THAN two decades, physicians, scientists, and engineers have had the dream that, one day, electronic picture archiving and communication systems (PACS) would replace film-based systems for radiology. Much progress has been made, and even though the dream has not yet been fully realized, digital techniques are being widely used. There are now several full-department PACS in operation. Far more commonplace are systems in use for teleradiology, centralized printing or archiving, support of intensive care units, or "mini-PACS" that serve a section of a radiology department.

At present, virtually all workstations that display medical images use a CRT. The limitations of the CRT are well known, but the methods used to overcome these limitations are less well known. One problem facing PACS sites is how to ensure that the same image displayed on different workstations will look the same to the observer. We want to be sure that we do not compromise one user or a set of users because of different internal display adjustments at different workstations. Further, we want the monitors to be adjusted so that the displays are constant over time. Thus, an image retrieved later should have the same display characteristics as its earlier displayed image. These issues are not trivial.

Unfortunately, because of limited experience with routine soft-copy diagnosis, the clinical consequences of degraded monitor performance are not well established. It also is important to note that because of low luminance level and limited spatial resolution of CRTs, the efficacy of soft-copy versus hardcopy diagnosis has been challenged. Furthermore, these issues of image quality of CRT display systems are being complicated by the trend to use high-performance color display systems for monochrome presentation of clinical images. This trend of using color display systems is very strong, particularly in the midresolution range of around $1,600 \times 1,200$ pixels. With color display systems,

the color-temperature for "white" ("monochrome") and the color coordinates for "white" vary substantially among color CRTs.

The problems of the presently used CRT display systems, particularly those that display digitally acquired full-field mammography systems, are so severe that the US Public Health Service's Office on Women's Health (PHS OMH) and the National Cancer Institute (NCI) sponsored a workshop on these issues. The objective of the workshop was to find display technology capable of showing mammograms imaged with these emerging digital mammography systems, which feature pixel matrices of $4,000 \times 5,000$ and a large dynamic range.

The idea for this special feature of image quality assurance for CRT display systems was born at the 1998 SPIE Conference on Medical Imaging. The conference offered a workshop on characterization of CRT display systems with three objectives: (1) definition of physical parameters for characterizing CRT display systems, (2) techniques for measuring these parameters in development laboratories, and (3) techniques for measuring the most relevant parameters in the field. The workshop included dialogue between the audience and an expert panel. Suggestions were offered to display manufacturers on how to characterize their systems so that performance specifications could become more comparable. Physicists and maintenance staff in hospitals were offered means for acceptance testing and quality assurance.

There was a strong desire to publish such information presented at this SPIE workshop and other related material. Dr Roger Bauman suggested a special feature section in several issues of the *Journal of Digital Imaging* as forum. This series begins with contributions from Dr Mertelmeier of Siemens Medical Corporation in Erlangen, Germany, and Dr Chakraborty of the University of Pennsylvania in Philadelphia.

Dr Mertelmeier begins with a brief introduction

to the general problems and advantages of using soft copy for primary radiology interpretations and then discusses the properties of the human visual system (HVS) relevant to the diagnostic process. Of particular importance are the spatial resolution of the eye-brain system and the sensitivity to flicker. The adaptation to the displayed radiological scene and the ambient illumination determine the dynamic range for operation of the HVS. When these parameters are known, it is possible to adjust the display monitor such that the information transfer to the eye is optimal, and then the monitor is "perceptually linearized." It is particularly comforting to note Dr Mertelmeier's assurance that the overall characteristics of the HVS are well suited to the visual tasks when presented on present-day radiological CRT displays. If the CRTs are set up properly, soft copy reading will be equivalent to reading from hard copy.

Dr Mertelmeier also reports that the German DIN working group (*Deutsche Industrie Norm*) is currently discussing a standard for acceptance testing of radiological image display devices. Most likely this standard will focus on the well-known SMPTE pattern (*Society of Motion Picture and Television Engineers*). Dr Mertelmeier emphasizes that routine monitor quality control must be available in clinical practice. These image quality measures must be simple enough to be applied as part of the daily routine. These same tests also might serve as elements of technical acceptance and constancy tests.

Dr Chakraborty discusses Computer Analysis of Mammographic Phantom Images (CAMPI) as a means to perform image quality control "objectively," ie, using an instrument—a computer—rather than a human observer. It demonstrates that high accuracy in the measurement of image quality can be achieved, particularly with respect to signal-

to-noise ratio, which in turn is highly dependent on the x-ray exposure.

At first glance, this report may not appear to fit the general topic of image quality control of CRTs. However, a brief look at the recent developments in mammography, namely the emergence of full-field digital mammography detectors and the problems with the display of these images on CRTs, shows that the tests described here need to be applied to the overall mammography system, including the display. In fact, they will permit objective estimation of how much information may be lost because of an improperly adjusted display. In the practical application of CAMPI to CRT image quality control, we envision a CCD camera to take images of the phantom images displayed on the CRT, and CAMPI to analyze the CCD camera images.

Whether practical or proposed, the methods described in these two articles present ideas that are essential if QA and QI programs are to be successfully applied to digital imaging systems. It is my belief that such programs are a necessity if PACS and PACS technologies are to be accepted by the clinical community. The community that has designed, implemented, and evaluated PACS and PACS technologies is perhaps best able to develop the tools for quality paradigms.

I thank the authors for their excellent contributions, the reviewers who provided such valuable feedback on the reports, and Dr Roger Bauman for his invitation to serve as guest editor. Unsolicited reports on CRT image quality continue to be of interest to the *Journal of Digital Imaging*.

Hans Roehrig, PhD
Guest Editor
Department of Radiology
and Optical Sciences Center
The University of Arizona
Tucson, AZ