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INTRODUCTION TO SPECIAL FEATURE

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Quality Assurance for Picture Archiving and Communication Systems (PACS) and PACS Technology Applications in Radiology

ALTHOUGH the idea that electronic picture archiving and communication systems (PACS) would replace film-based systems for radiology has not yet been fully realized, digital techniques are being widely used. There are also a few large-scale PACS in operation; the US Department of Defense Medical Diagnostic Imaging Support System sites, the Baltimore Veterans Administration Hospital, and the SMZO Hospital in Austria are examples. Far more commonplace are systems in use for teleradiology, centralized printing or archiving, support of intensive care units, or "miniPACS" that serve a section of a radiology department.

Just as much of the logistics for departmental operation have been established around film-based operation, so have the quality control (QC), quality assurance (QA), and quality improvement (QI) plans. Quality paradigms have been established for digital imaging techniques, but largely directed at the end result of producing a film representation of the images. For systems that capture images, transmit them, store them digitally, and display them on cathode-ray tube (CRT) monitors, how are we to perform the same type of quality assurance that we do for film? As regulatory and accrediting agencies acknowledge the applicability (or desirability) of digital imaging technologies, it is likely that they will require QA and QI programs.

The community that has designed, implemented, and evaluated PACS and PACS technologies is perhaps best able to develop the tools for quality paradigms. The focus of this issue of the *Journal of Digital Imaging* is on methods that can be used in support of QA. A section on quality paradigms in subsequent issues will include papers devoted to this subject as well, and the editors of the *Journal of Digital Imaging* welcome your contributions in this area.

We begin this series with papers devoted to two main areas for which QA is thought by many to be essential; for the film digitizer as an input device and for the CRT monitor as an output device. Despite the movement of plain radiography to storage phosphor imaging (computed radiography [CR]), virtually all departments have large archives of film that may need to be digitized if comparisons are to be made on an electronic workstation. Also, current CR imaging is not thought by all radiologists to be suitable for all radiographic imaging methods, so digitizing film remains an option as an input technique.

Dr Ethan Halpern (Thomas Jefferson University Hospital, Philadelphia, PA) has developed a precision-printed film test pattern for performing QC/QA procedures on film digitizers. His paper describes this test pattern, its use, and the setup of a film digitizer QC program based on measurements made with it. Though a laser or noncoherent light-scanning film digitizer seems as though it should be a robust device, there are nonetheless a variety of problems that can befall such equipment. Some of these problems, such as loss of the lower bits of the analog-to-digital converter or variation in scanning speed, are not readily apparent on digitized medical images,

owing to the masking of them by the complexity of the image. A test image with known patterns and areas that stress the limits of the digitizer electronics will help make such problems apparent.

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

These problems are not trivial to solve, and there are two approaches described in this issue of the *Journal.* David Parsons and Drs Yongmin Kim and David Haynor (University of Washington, Seattle) describe a method that is based on a series of photometric measurements of test patterns displayed on each monitor. The QC program proposed in this paper also includes displays for measurement of geometric distortion and veiling glare and determining how all of these parameters vary over time. An important feature of this method is one that is desirable for any QC or QA program; the tests are relatively simple and quick to perform. The end result of implementation of a program such as the one these authors recommend is that monitors can be kept adjusted to some desirable set of display characteristics and that variances exceeding those expected can be used to initiate repair and replacement cycles.

The problem of how to set display parameters so that images look the same, even across workstations from different manufacturers, is one that is a step beyond the monitor QC process (though the QC processes can be used to maintain the optimized parameters once set). One approach to solving this problem is to perform perceptual linearization of the display systems. The paper by Hemminger et al describes this process for CRT-based displays. The perceptual linearization process does not necessarily guarantee an optimized image insofar as observer performance is concerned. However, it does guarantee that the information transfer to the observer from a display system is maximized and that equal changes in input value to a display system result in equal changes in the visually perceived result. It can also be used across different display systems, so that, eg, the perceived brightness differences from a film on a lightbox can be matched to those of the same image displayed on a CRT. The method relies on determining how the luminance of a display system changes in response to different digital driving levels and how the human observer perceives a brightness level in response to a given monitor luminance value. The authors of this paper describe these processes along with some of the research that has gone into determining how the human observer responds to luminance changes. The authors also point out deficiencies of present CRT display systems that limit the extent to which perceptual linearization can be performed.

Whether practical or proposed, the methods described in these papers present ideas that are essential if QA and QI programs are going 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.

I thank the authors for their excellent contributions, the reviewers who provided such valuable constructive criticism of the papers, and Dr Roger Bauman, Editor-in-Chief, for his invitation to serve as guest editor. The *Journal* continues to seek contributed papers for this series.

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