

# Quality Assurance Program in the Digital Medical Enterprise

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The evolution of medical imaging towards the ultimate totally digital imaging has accelerated over the past decade. An enterprise-wide system enables clinicians and referring physicians access to full fidelity-images anytime, anyplace, on-demand across the network. The rapid deployment of digital imaging modalities in a digital medical enterprise calls for a rigorous quality assurance (QA) program. This paper reviews the methods and processes that are necessary to evaluate, maintain and perform quality control on digital workstation displays, computed radiography and digital radiography equipment, picture archiving and communications systems. Digital x-ray imaging systems are increasingly being implemented into the digital medical enterprise and research is needed to provide advice on issues such as quality assurance, performance comparison and optimization. There is a unique opportunity challenging us to develop a QA program for those components of the digital medical enterprise not addressed in standard methods. Ultimately, knowledge of process and technology is required for the implementation of a successful QA program to assure highest quality in patient care.

**Keywords:** Digital Imaging, Quality Assurance, Computed Radiography, Digital Radiography, Display Workstation

## 1. BASICS OF A DIGITAL IMAGING DEPARTMENT

The evolution of medical imaging towards the ultimate totally digital imaging has accelerated over the past decade. The change from photographic film to digital image began with the invention of computed tomography (CT) and gathered momentum with the invention of other digital imaging modalities such as digital subtraction angiography (DSA), magnetic resonance imaging (MRI), single photon emission computed tomography (SPECT), computed radiography (CR) and digital radiography (DR) [1,2]. This transition was further enhanced by the development of high speed computing power and advanced image processing software that offered solutions to the problems of data retrieval and transmission to remote locations such as the emergency room, operating theatres, at the patient's bedside as well as in the radiology reading room. The digital imaging department has been a reality for more than a decade now and consists of entirely digital imaging devices (CR, DR, CT, MRI, SPECT, PET/CT, etc.), a distributed image display workstations, and a picture archiving and communications system (PACS). The rapid deployment of digital imaging modalities in a digital medical enterprise calls for a rigorous quality assurance (QA) program.

The paradigm shift in imaging chain from a traditional film-based imaging department to a digital imaging department is depicted in Fig. 1 below [3].

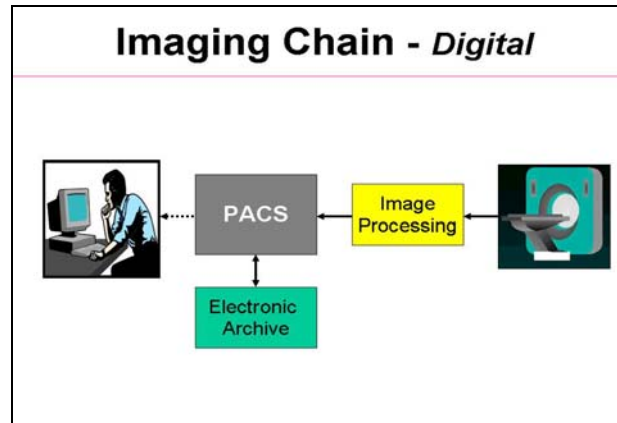
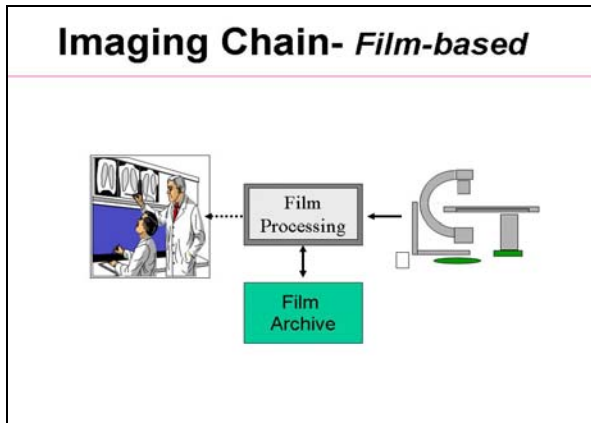


Fig. 1 (a) Traditional film-based imaging chain

Fig. 1 (b) The digital imaging chain [3]

## 2. DIGITAL IMAGING DEPARTMENT - UNIQUE QA PROGRAM

The process of designing an effective QA program includes:

- (1) Understand the process of image formation and reporting, work flow (from production to delivery to the referring physician).
- (2) The QA team should be formed, and should include medical physicist, radiologist, PACS administrator, technologist, department administrator, clinician, and an IT representative.
- (3) The QA team should examine both image production and image display procedures. Indicators/QC tests should be created based on the work flow developed in the first step, centered on relevant points to examine the quality of the imaging procedure.

Each digital image should be inspected for:

Positioning and markers
Density/contrast/artifacts
Proper radiation exposure to the imaging plate
Processing parameters

For image display, the QA team needs to ensure that images contain correct patient and procedure demographics, and that image integrity is assured. In addition, the team must proactively monitor the status of the network and prepare plans for operation during system downtime. Multiple hierarchy of backup plans and disaster prevention are also needed.

The QA team needs to meet and review periodically the results of the QA indicators. It may be possible to achieve quality improvements such as a reduction in frequency of QA events through root-cause analysis. Ultimately, knowledge of process and technology is required for a successful QA program.

QA for a digital imaging department adds a new dimension and demand to the existing procedures for standard methods (conventional film-based). The clinical standards for clinical usage are largely unchanged from those of the more standard imaging departments. Present procedures for accreditation and regulation do not address this issue. Hence there is a unique opportunity challenging us to develop a comprehensive QA program for those components of the digital imaging department not addressed in standard methods.

### 3. DIGITAL IMAGING DEPARTMENT - UNIQUE QA REQUIREMENTS

The digital imaging department has at least three important components that are not covered by QA for conventional standard departments: (1). the image display workstation, (2). the computed radiography (CR) and digital radiography (DR) imaging equipment and (3). the picture archiving and communications system (PACS).

#### 3.1 THE IMAGE DISPLAY WORKSTATION

The image display workstation is a critical part of the diagnostic process in a digital imaging department as shown in Fig. 2. Studies have shown that both the luminance of display devices and ambient viewing conditions have a direct effect on diagnostic quality [4,5]. There is still no international accepted standards and guidelines for the evaluation of display devices [6]. The issue is a little more complex now that there are two types of monitors, cathode ray tubes (CRTs) and liquid crystal displays (LCD).

Most centers have adopted standards proposed by the Society of Motion Picture and Television Engineers (SMPTE) (Fig. 3) and suggested by the workstation manufacturer [7,8]. More recently the AAPM developed the TG18-QC test pattern (Fig. 4) that is specifically designed for medical imaging performance evaluation [9].

These test patterns provide users of medical diagnostic imaging systems with a comprehensive test pattern for day-to-day operational checks and adjustments of focus, brightness and contrast, resolution response, uniformity, and linearity of viewing monitors and hard-copy printings. One of the important tests is the use of a photometer to check the monitor's conformance with the DICOM Grayscale Standard Display Function (GSDF).



Fig. 2.  
A critical component for accurate diagnosis in a digital imaging department is the image display workstation where the radiologists observe the images to make a diagnosis. All clinical information passes through the display. Note the low ambient lighting condition.

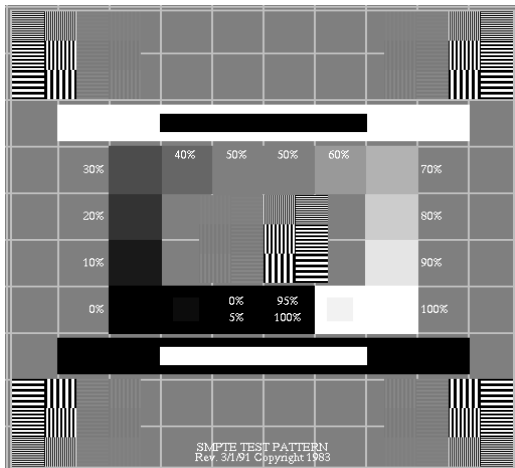


Fig. 3. SMPTE pattern. (1) The gray scale is shown as a series of squares in the center of the image that range from black (0%) to white (100%) in a semi-rectangle. The 0% and 100% squares each contain smaller squares within them that represent signal level steps of 5% and 95%, respectively. The brightness and contrast of the monitor are adequately set if the 5% squares at both ends of gray scale are visible. (2) The spatial resolution (linearity) and aliasing (distortion) of the monitor are located in each corner and the center of the image. They are within acceptable limits if the high contrast bar patterns in the test image are distinct as simple patterns of black and white pairs.



Fig. 4 The TG18-QC test pattern. The pattern contains: (1) 16 luminance patches at the corners of each of which are four low contrast targets for evaluating luminance and low-contrast response; (2) two continuous grayscale ramp bars for evaluating display bit-depth; (3) Cx and line- pair targets at the center and four corners and a scoring Cx reference for evaluating display resolution; (4) white-black bars for evaluating video artifacts; and (5) 5% and 95% embedded patches and low-contrast "QUALITY CONTROL" letters with variable contrast within different luminance backgrounds, for evaluating the grayscale rendition/ luminance response of the display device.

### 3.2 COMPUTED RADIOGRAPHY (CR) AND DIGITAL RADIOGRAPHY (DR) EQUIPMENT

The second major component of a digital imaging department is the CR and DR. Due to the rapid technological advances and the reduction in cost, more and more hospitals are converting to CR and DR.

Task Group 10 of the Diagnostic Committee of the American Association of Physicists in Medicine has undertaken the task of establishing a standard of performance for QC of CR equipment. The AAPM has not released the Task Group 10 standard but field test details had been published [10].

This standard addresses the characteristics such as:

- Phosphor Plate Dark Noise
- System Linearity, Auto-Ranging and Exposure Response
- Receptor Reproducibility, Density Uniformity & Artifact Analysis
- Phosphor Plate/Cassette Throughput
- Laser Beam Function
- Spatial Resolution
- Wire Mesh Test - Resolution Uniformity across Receptor



Fig. 5 A computed radiography (CR) reader. Shown here is a model with four input trays for simultaneous reading. Rigorous QC tests are necessary to produce optimum image quality. (Courtesy of Fujifilm)

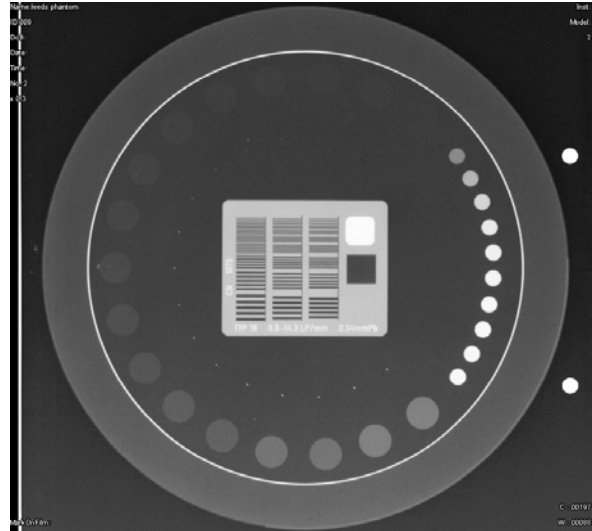
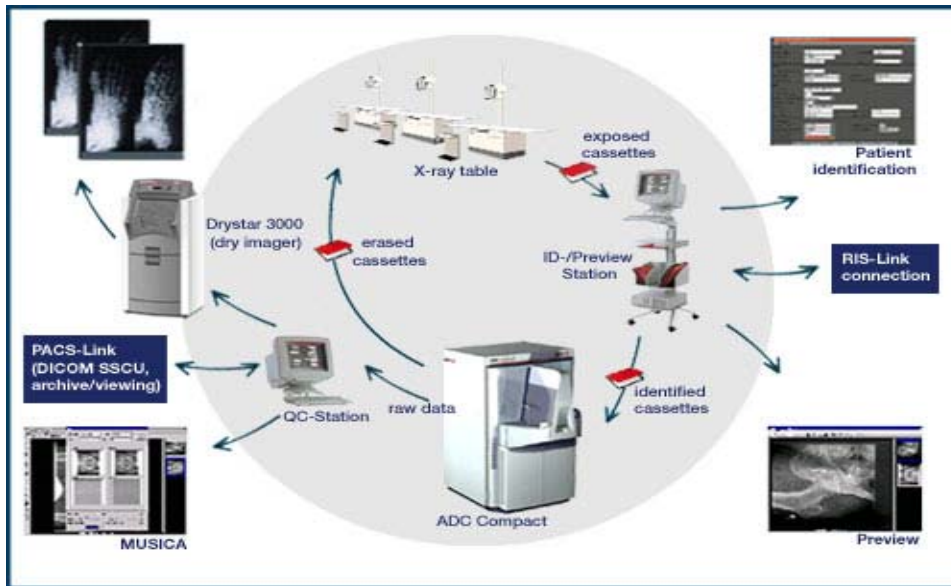


Fig. 6. A radiograph of an image quality phantom. The embedded test objects include low and high contrast objects, spatial resolution bar phantom, and gray scale objects. Many scientific and commercial test objects or phantoms to measure, assess and perform quality control in different parts of the imaging chain have been made. The Leeds TOR from the University of Leeds, U.K. shown here is one such example.

### 3.3 PICTURE ARCHIVING AND COMMUNICATIONS SYSTEM (PACS)

The PACS presents an exceptional problem for the digital imaging department, both technically and economically. This is due mainly to the complexity of hospital imaging work flow environment and the accelerated obsolescence of information technology hardware and software. Over the past decade *Hospital Information Systems (HIS)* have begun the process of integrating the distribution of information of all types (laboratory results, orders of supplies, billing, admission and discharge, patient records, etc.) into a single enterprise-wide entity. Interfacing of the HIS with the *Radiology Information System (RIS)* has become a complicated major issue.

Current QC issues that are being addressed include archiving, transmission, integration, network security, DICOM compatibility, modality inter-operability, data integrity, and patient confidentiality [11].



**Fig. 7** A typical PACS linking to several modalities and accessories. Work flow is indicated. (Courtesy of Afga)

#### 4. FUTURE SCENARIO

QA of medical imaging becomes more critical with the increasing importance of imaging in 21<sup>st</sup> century medical enterprise. For optimum performance of digital imaging equipment every player in the enterprise must know and understand the performance and relationship of the major elements of the imaging chain [12, 13].

There is a continuing trend towards transforming radiology departments to fully digital medical imaging departments. This trend is driven by efficiency that information technological systems offer. This development creates a new set of QA demands that must be resolved. Professional organizations such as the American Association of Physicists in Medicine (AAPM), American College of Radiology (ACR), and Institute of Physics and Engineering in Medicine (IPEM) have formed task groups to formulate solutions to various QA problems. Ultimately, knowledge of process and technology is required for the implementation of a successful QA program to assure highest quality in patient care. A rigorous and effective QA program can result in highest quality patient care and improvement of quality of life.

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