Design Considerations in Optimizing a Specimen Radiography System for Breast Applications

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Introduction

This paper discusses considerations that were made in the development of the Trident™ specimen radiography system to optimize image quality and work flow. The paper provides an image quality comparison of the Trident specimen radiography system with other commercial systems.

The Trident specimen radiography system offers direct capture detector technology.

Image Quality in Specimen Radiography

Modulation Transfer Function

The modulation transfer function (MTF) is an important figure of merit of an imaging system that indicates its ability to capture, transfer, and display information about features with fine spatial detail. The MTF is especially important in a mammographic imaging system since radiologists must resolve not only the presence of, but also the morphology of micro calcifications whose dimensions can be less than 200 µm. Hologic's Trident specimen radiography system uses a digital x-ray detector based on the direct conversion of x-rays to charge in a layer of amorphous selenium. The selenium layer is coated on a thin-film transistor array with a pixel pitch of 70 µm. This detector technology has been demonstrated to have excellent MTF characteristics as well as a high quantum efficiency.[1]

The MTF of the Trident detector was measured using the Fujita method.[2] In this method, a 10 µm slit in a metallic foil is placed on the detector at a small angle to the rows of pixels. An x-ray image of the slit is captured using 25 kVp x-rays. The image of the slit is mathematically analyzed to derive the MTF. The results of this analysis are shown in Figure 1, along with MTF measurements on two commercial specimen systems made under similar conditions.

The x-ray focal spot size of the Trident system is 50 µm and the SID is about 50 cm. This configuration ensures that focal spot blur has only a minimal effect on MTF for contact, 1.5x and 2.0x magnifications.

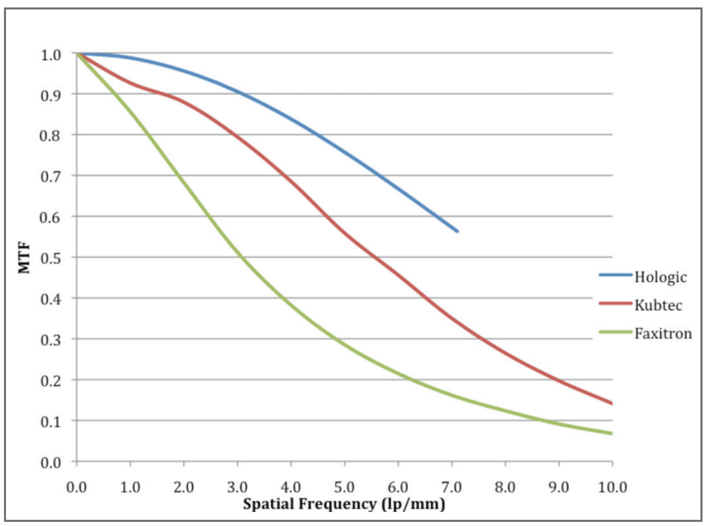


Figure 1 Comparative MTFs of Hologic Trident, Kubtec XPERT 40, and Faxitron DX-50 Specimen Radiography Systems

Quantum Efficiency

Since specimen radiography involves excised, inanimate tissue, x-ray dose is not a concern, hence quantum efficiency plays a relatively minor role. However, high quantum efficiency is desirable in minimizing the length of x-ray exposures and reducing image noise. The Trident x-ray detector's selenium layer absorbs more than 98% of incident 25 kVp x-rays. The analog electronics in the system are exceptionally quiet and the 14-bit analog-to-digital converters ensure noise-free transfer of image information to the display system.

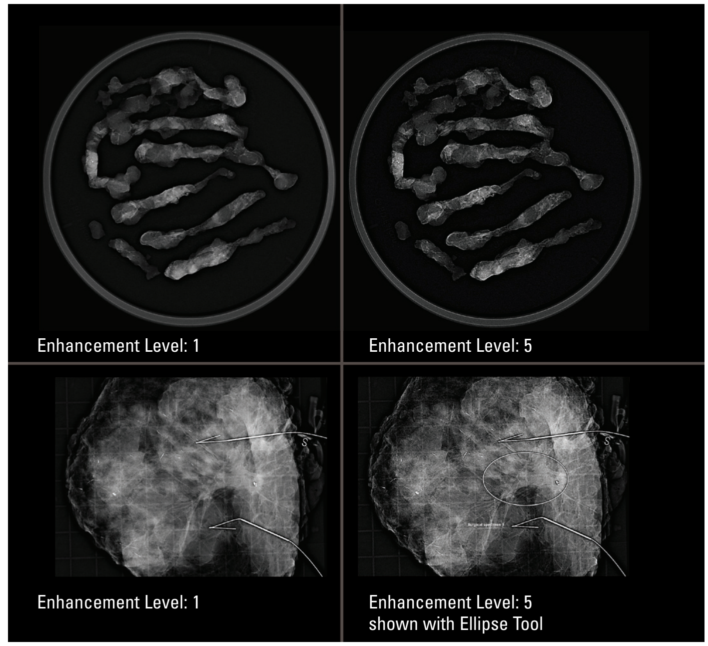
Artifacts

The most common cause for objectionable artifacts in digital x-ray images is gaps or seams between various elements of the detector. Seams in x-ray detectors can result in apparent gaps in the images, discontinuities in density between chips that change with temperature and x-ray technique, and loss of diagnostic information at the seams.

The Trident x-ray detector is monolithic and has no seams so the images it produces are smooth and artifact-free. The detector has a thermal controller that maintains the temperature of the selenium at an optimum value. This assures that dark currents and gain calibrations are unaffected by ambient temperature and time, thereby reducing artifacts further.

Image Enhancement

Digital image enhancement was designed for the Trident system specifically to optimize the display of specimen images. The basic processing automatically applies sharpening so that the visibility of fine features is improved, and compresses the dynamic range of the image so that both the periphery and the interior of the specimen can be visualized simultaneously. Although the image processing is designed to present specimen images to the user without the need for further manipulation, additional sharpening can be applied in five levels further to enhance the visibility of calcifications, and standard image manipulation functions, such as window/level, magnify, and invert, are available to satisfy individual users' preferences.



The Enhanced Visualization tool offers 5 user-selectable image sharpening levels. Tools and annotations are also available in multi-up mode.

Automatic Exposure Control

The Trident specimen radiography system incorporates automatic exposure control (AEC) that selects the optimum x-ray technique (kV and mAs) for the specimen under study. The AEC sequence first captures a rough image of the specimen using a short x-ray exposure at a fixed, mid-range technique. This image is analyzed by detector software to determine the densest region of the specimen. System software then decides what kV and mAs to use for the diagnostic exposure based on the value of the densest area of the specimen. The algorithm that chooses the x-ray technique is designed to maintain the contrast-to-noise ratio of the image at a level similar to an upright mammography system over the range of specimen thicknesses from zero to seven centimeters.

Trident also provides manual x-ray exposure control that enables the user to select kV and mAs over the full range available, 20 to 35 kV and 0.5 to 10 mAs.

Work Flow

Calibration

As already noted, the Trident detector has a thermal controller that maintains the selenium temperature at a fixed value. This stabilizes the electronic properties of the detector and makes them insensitive to ambient temperature. Dark offset calibration and AEC calibration are therefore required only once and are performed at the factory.

Gain calibration is an operation that compensates for pixel-to-pixel variations in x-ray sensitivity of the system. Because of the temperature control, it is also stable and only needs to be performed once a month by the end user. Gain calibration is fully automatic and consists of capturing six open field images, averaging them, and mathematically manipulating them to create the gain calibration file. When the gain calibration expires at the end of the month, the user is prompted to initiate the calibration when she logs off the system. The calibration procedure, which takes less than five minutes, proceeds automatically, after which the system either shuts down or returns to the login screen, according to the user's choice.

User Interface

The Trident user interface was designed to be ergonomic and to minimize the number of steps required to capture, review, and store specimen images. Information for scheduled patients can be retrieved from the hospital's RIS or entered manually by the user. Once a patient procedure is opened, the Trident system is always ready to capture the next x-ray image with a single button push, and image quality on the high-resolution monitor are assured by AEC and image processing. Captured images are sent automatically to configured workstations or printers when a study is closed, or manually under user control. System controls are laid out so that the most commonly used functions are available without extra mouse clicks.

In Summary

As shown in this paper, Hologic's Trident specimen radiography system has proven superiority over its competitors in image quality with better MTF and quantum efficiency for visualizing lesions and calcifications in core and surgical specimens due to its digital x-ray detector technology. Users gain significant advantages in workflow with tissue specific AEC, advanced software tools and single click for image acquisition and export.

References

[1] J. Yorker, L. Jeromin, D. Lee, E. Palecki, K. Golden, Z. Jing, "Characterization of a full field digital mammography detector based on direct x-ray conversion in selenium," *Physics of Medical Imaging 2002*, SPIE Vol. 4682, pp. 21-29, February 2002.

[2] H. Fujita, D. Tsai, T. Itoh, K. Doi, J. Morishita, K. Ueda, A. Ohtsusuka, "A simple method for determining the modulation transfer function in digital mammography," *IEEE Transactions on Medical Imaging*, Vol. 11 (2), pp. 34-39, 1992.

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