Clinical evaluation of a full field digital projection radiography detector

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ABSTRACT

Efforts to integrate projection radiography into the digital environment have, to date, required signal degrading steps. The purpose of this study was to compare new directly acquired digital projection radiographic images to conventional film screen images. 50 paired images (25 chest and 25 abdomen) were obtained under identical conditions and at comparable exposures using a new digital system and a conventional 200 speed film-screen system. This new direct x-ray converting full field 14 x 17 inch detector (Sterling Imaging) uses selenium coupled to a 2560 x 3072 thin film transistor array with a pixel pitch of 139 microns. The detector was easily retrofitted to existing radiographic equipment. After applying appropriate algorithms to obtain images that were comparable in gray scale appearance to conventional film, the 14 bit digital images were printed at full resolution (8 bit) on laser film. Detail evaluation of these paired images under identical viewing conditions, using standardized protocols that were formulated prior to imaging, was performed by three experienced radiologists for each body area. The hard copy clinical digital images were judged by all of the expert panel of radiologists to be superior or equivalent to their paired conventional film screen study (t-value confidence level of 10^{-6} for chest and .03 for abdomen).

1. INTRODUCTION

Projection radiography has been the last roadblock to achieving a true, diagnostically, uncompromising, totally digital radiology department (1). To date, all efforts to integrate projection radiography into the digital environment have been compromises requiring signal-degrading intermediate steps. These include film digitizers, storage phosphor scanners and low resolution, high cost large field analog to digital converters of image-intensifier video outputs. These systems have failed to meet the potential of the digital department -- digitizers and storage phosphor scanners frequently require central processing and, therefore, in addition provide poor integration into picture archiving and communications systems from remote location. Currently, several high resolution large field (14 inch by 17 inch) digital detectors are under development or in clinical trials. However, only one system directly converts the incident x-rays to a digital image without degrading light scattering intermediaries. This full field 14 x 17 inch digital projection radiography detector developed by Sterling Imaging uses selenium coupled to a 2560 x 3072 thin film transistor array with a pixel pitch of 139 x 139 microns. The theory of operation and the description of this detector has been reported previously. Since this detector directly converts the incident x-ray photons into charge, it demonstrates an exceptionally high modulation transfer function (MTF), (see Figure 1) good spatial resolution and high detective quantum efficiency (DQE). With the uncoupling of the detector from the display it allows for applications of appropriate computer imaging filtering techniques. This new digital system was evaluated by statistical comparison of 25 chest and 25 abdomen images to conventional film-screen images in 50 patients.

2. METHODS OF PROCEDURE

2.1 Subject recruitment

50 ambulatory patients 18 years of age or older who were referred to the radiology department for a clinically indicated chest or abdomen examination were recruited to participate in this evaluation protocol. All volunteers were taken consecutively as they entered the radiology department without selection.

2.2 Image formation

25 paired single view PA chest and 25 paired supine abdomen x-ray images were obtained using the selenium based digital system and a conventional film-screen system (Sterling Diagnostic Imaging Ultravision Fast Detail Screen with UVL film-200 speed). For scatter reduction all chest images were taken using air gap technique (6-8 inch air gap with 10 foot focal detector distance) and a reciprocating bucky grid was used for all supine abdomen images. All

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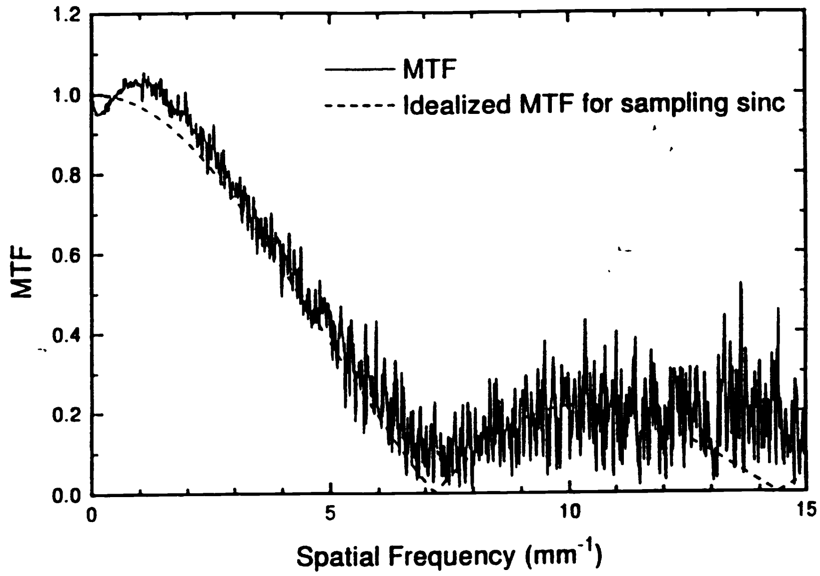

Figure 1 MTF of the Sterling selenium detector measured using a slanted edge method

image pairs were produced in the same radiographic room using the same equipment (GE Advantix). The conventional film-screen image of each pair was recorded first using photo-timed automatic exposure control, 110 kVp for the chest images, and depending on patient size 70 or 75 kVp for the supine abdomen images. The photo-timed exposure values were recorded following each film-screen image and the same MAS and kVp was used under manual fixed control for the digital paired image. Identical MAS could not always be obtained due to the mechanical limitations of the manual MAS control, however the closest obtainable value was used (+/- 5%) for the digital images. The digital images were laser printed with pre-established algorithms on 14 x 17 inch film using an LP 400 Sterling Diagnostic Imaging laser camera (2560 x 3072 matrix, 8 bit).

2.3 Image evaluation

Prior to obtaining the images, evaluation protocols were established by experienced radiologists for each body area. These protocols listed visual details that are used clinically in establishing the diagnostic content of an image. For the chest images 22 features were evaluated for detail, (Table 1). Eleven features were evaluated for detail in the abdominal images, (Table 2). Figures 2, 3, 4, and 5 are examples of four of the image pairs used in the comparison evaluation.

Table 1

Chest Evaluation Protocol

22 features evaluated for detail

- **Mediastinum (4)**
- **Lungs/Pleura (11)**
- **Soft Tissues (3)**
- **Bony Structures (2)**
- **Miscellaneous (2)**

Rated: 0-5: Highest possible score 110

Table 2

Abdomen Image Evaluation

11 features evaluated for detail

- **Solid Organ Outlines (3)**
- **Soft Tissues (3)**
- **Gas-filled Structures (2)**
- **Calcifications (1)**
- **Appliances (1)**
- **Bony Structures (1)**

Rated: 0-5: Highest possible score 55

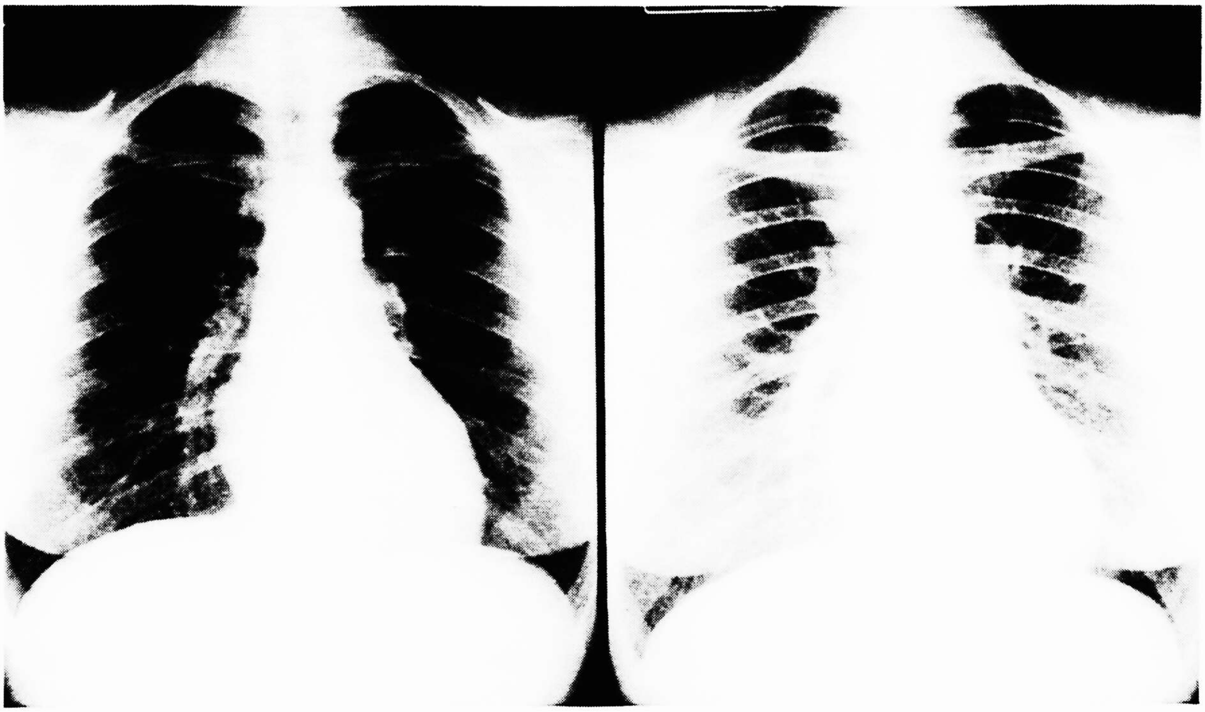

Figure 2 Chest image pair-digital image on left

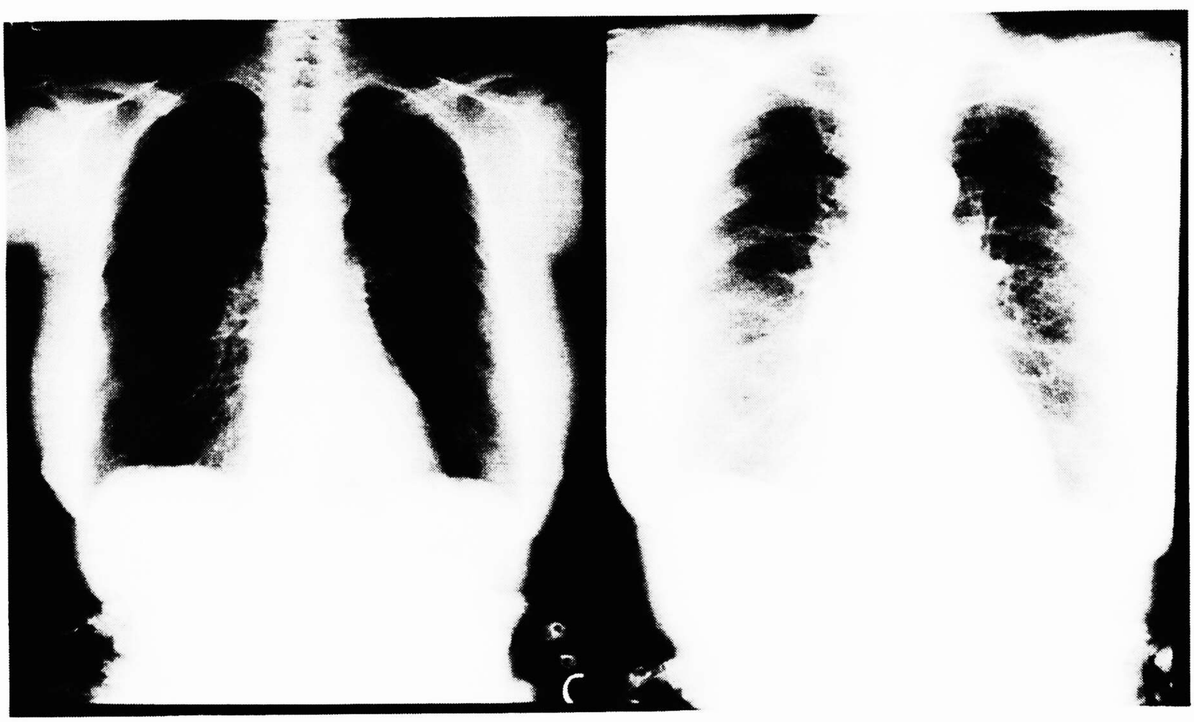

Figure 3 Chest image pair-digital image on left

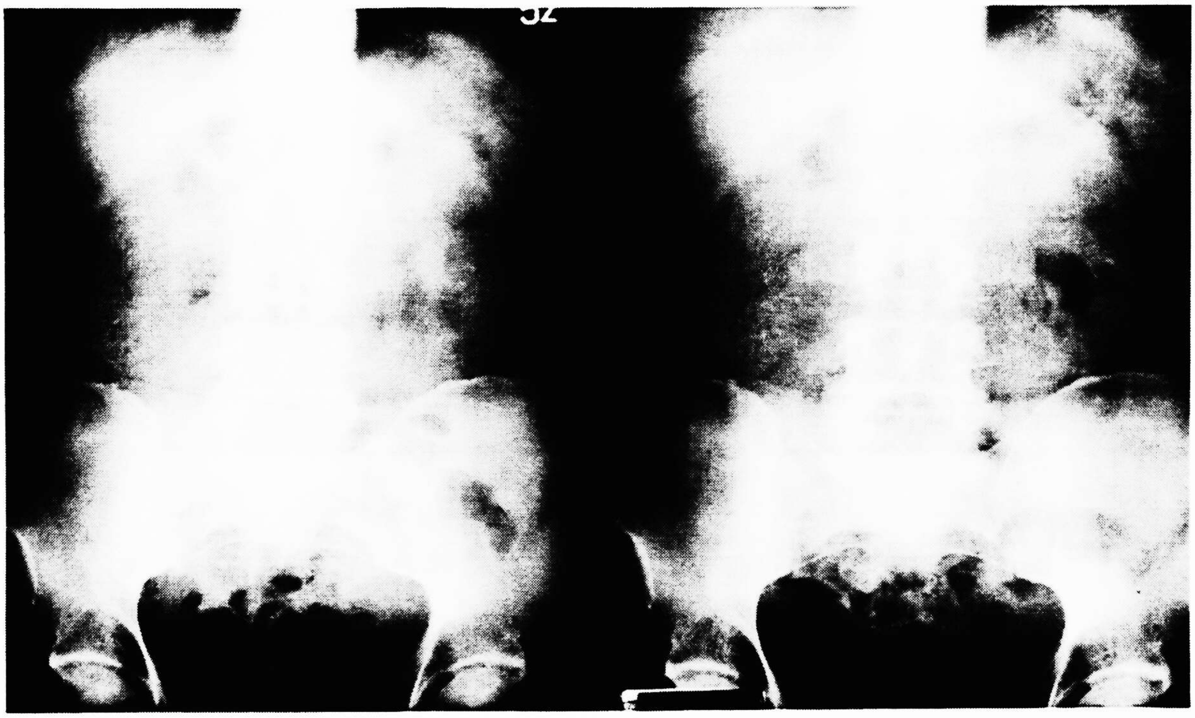

Figure 4 Abdomen image pair-digital image on left

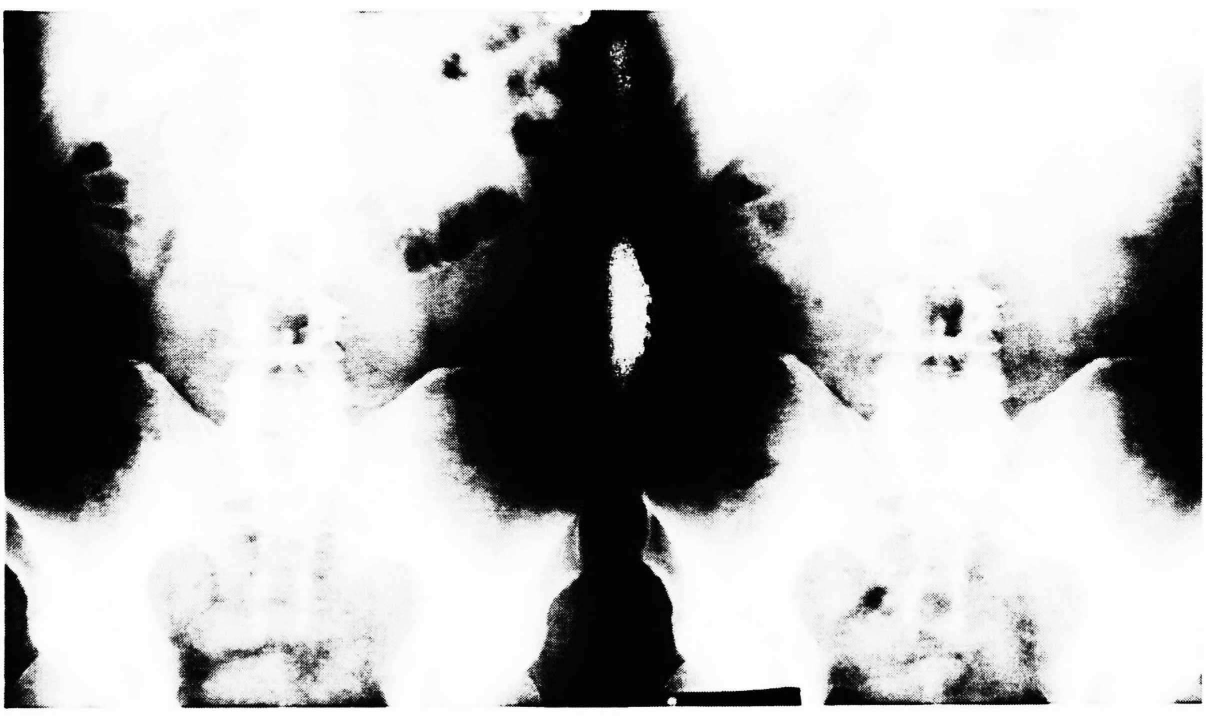

Figure 5 Abdomen image pair-digital image on left

Since the digital image of each pair would be obvious to the observers a double blind study could not be performed. It was decided that the 50 images for each body area should be unpaired and mixed at random and evaluated individually by three experienced radiologists for each body area using the pre-established detail evaluation form. All images were observed under identical viewing conditions using a single conventional x-ray view box with the randomized images being presented to each experienced radiologist sequentially. All images were presented in the same sequence to each radiologist observer. Each specific detail for each image was rated by the radiologist on a score of 0-5 (110 maximum for the chest and 55 maximum for the abdomen) and a total raw score for each image obtained by simple addition of the rating for each detail. A Student t-test was used to evaluate the significance of the difference of the mean rating score of the digital images and the conventional film-screen images to establish the equivalence or superiority of either the digital or film-screen images for each body area.

3. RESULTS

3.1 Chest

Table 3 demonstrates the statistically significant superiority of the digital images as compared to the conventional film-screen images, as judged by the three experienced radiologist observers when the images were reviewed individually in random sequence (confidence level 10^{-6}). When the images were resorted back into pairs, raw score comparison of each pair once again reveals the marked preference for the digital images by each observer as shown in Table 4.

3.2 Abdomen

Mean raw scores for the abdominal digital images were higher than the film-screen image scores, however, this difference was only shown to be statistically significantly superior by one of the three expert observers (confidence level .03). The rating scores from the other two observers demonstrated statistically significant equivalence as shown in Table 5. Although firm statistical superiority of the digital images could not be established for the abdomen once again when the image detail raw scores were compared as pairs, all observers preferred the majority of the digital images as shown in Table 6.

The observed statistical comparison differences between the paired chest images, with their greater high frequency object content and abdomen images is most likely explained by the superior MTF of the digital system as compared to the film-screen system.

Table 3

Chest Image Evaluation

OBSERVER #1	MEAN SCORE	STD* DEVIATION	T-VALUE	CONFIDENCE LEVEL (P)
FILM IMAGES	50.04	4.869	-9.72498	10^{-7}
DIGITAL IMAGES	61.88	6.710		
OBSERVER #2				
FILM IMAGES	65.16	7.375	-10.4618	10^{-7}
DIGITAL IMAGES	77.92	5.619		
OBSERVER #3				
FILM IMAGES	59.60	7.848	-6.50754	1×10^{-6}
DIGITAL IMAGES	67.40	6.311		

* Relates more to patient body habitus than variation in image quality

Table 4

Paired Image Comparison
Chest

	PREFERRED IMAGE FILM-SCREEN	PREFERRED IMAGE DIGITAL	CONFIDENCE LEVEL
OBSERVER #1	1	24	10^{-7}
OBSERVER #2	0	25	10^{-7}
OBSERVER #3	3	22	10^{-7}

Table 5

Abdomen Image Evaluation

OBSERVER #1	MEAN SCORE	STD* DEVIATION	T-VALUE	CONFIDENCE LEVEL (P)
FILM IMAGES	24.60	6.344	-1.478	.152
DIGITAL IMAGES	25.64	7.239		
OBSERVER #2				
FILM IMAGES	24.32	6.669	-1.52367	.141
DIGITAL IMAGES	26.08	7.331		
OBSERVER #3				
FILM IMAGES	28.00	8.031	-2.25874	.033
DIGITAL IMAGES	30.44	9.023		

* Relates more to patient body habitus than variation in image quality

Table 6

Paired Image Comparison
Abdomen

	PREFERRED IMAGE FILM-SCREEN	PREFERRED IMAGE DIGITAL	CONFIDENCE LEVEL
OBSERVER #1	8	17	.152
OBSERVER #2	10	15	.141
OBSERVER #3	8	17	.033

4. CONCLUSIONS

Initial studies of 50 patients reveal that diagnostic projection radiographic images are produced, without significant equipment modification with the new "DirectRay" digital selenium system that are equivalent or superior to conventional film-screen images at the same x-ray exposure. This newly developed system should finally offer effective integration of projection radiographs into PACS with either workstation, CRT or laser printer hard copy images available for radiologic interpretation or distributable for remote viewing.

5. REFERENCES

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