Visibility of Normal Thoracic Anatomic Landmarks on Storage Phosphor Digital Radiography Versus Conventional Radiography

Eli Konen MD, Inesa Greenberg MD and Judith Rozenman MD

Department of Diagnostic Imaging, Sheba Medical Center, Tel Hashomer, Israel

Key words: digital radiography, chest X-ray, thoracic imaging, normal anatomy

Abstract

Background: Chest radiography is still the most frequently performed radiologic imaging study. Digital radiography is gradually replacing the conventional systems.

Objectives: To compare the subjective visibility of normal anatomic landmarks in the chest on storage phosphor-based digital radiographs versus conventional screen-film radiographs.

Methods: Digital phosphor-based and screen-film posteroanterior chest radiographs were obtained during 1 year in 140 asymptomatic patients without any known pulmonary disease (119 men, 21 women; mean age 52.1 years, range 23–86). Both sets of films were independently compared by two experienced radiologists in different sessions. The visibility of each of the following anatomic landmarks was graded from 1 to 3: pulmonary fissures, carina, bronchi to left upper lobe, right upper lobe and left lower lobe, bronchus intermedius, anterior and posterior junctional lines, and vessels behind the heart and diaphragm. Additionally, subjective general quality impression of each radiograph was graded similarly. Statistical analyses were performed using the chi-square test. A P value less than 0.05 was considered significant.

Results: Visibility with the digital images was statistically significantly higher for the carina, left lower lobe bronchus, bronchus intermedius, and vessels behind the heart and diaphragm. Subjective general quality impression of digital radiographs was also higher ($P < 0.001$). No significant visibility differences were found for pulmonary fissures or junctional lines.

Conclusion: Subjective visibility of anatomic structures behind the heart and diaphragm and at the hilae is significantly improved with phosphor-based digital radiography compared with conventional screen-film radiography. This suggests that pathologic processes such as pulmonary nodules, masses or consolidations projected over those structures may be more easily and reliably depicted on digital than on conventional chest X-rays.

IMAJ 2005;7:495–497

Chest radiography is still the most frequently performed radiologic imaging study [1]. For many years conventional film-screen radiography systems provided good image quality, high spatial resolution, and generally low costs. However, typical disadvantages of film-screen radiography techniques include a limited exposure range, a rather high retake rate, and the inflexibility of image display and film management [2].

Due to recent computer technology and storage capacity developments, the use of PACS (picture archiving and communication system) is continually increasing. The accurate implementation of PACS depends on digital radiography techniques. Digital radiography systems offer an instant image display, a wide dynamic range, and a linear signal response [3,4]. The first step in digital chest radiography was the use of storage phosphor plates, which are popular because of their compatibility with existing radiography equipment. During this transitional period, radiologists are required to undergo a process of self-adjustment in which they have to "translate" the appearance of various diseases as well as normal anatomy from the well-known conventional films, to their new appearance on the digital images.

The aim of the present study was to evaluate the differences in visibility of 12 anatomic landmarks on storage phosphor-based images (using a new commercial processing station) as compared with conventional images (using our old operating system before disposal). Visibility improvement of normal anatomic structures in certain fields of the chest (especially behind the diaphragm and the mediastinum) implies a potential improvement in depicting abnormalities in the same areas. Previous studies addressing this issue [5–7] were based on early prototype digital stations and state-of-the-art, relatively new conventional systems. Since most imaging departments usually change old conventional equipment for the newest available commercial digital systems, our findings might be of interest and help to radiologists facing a similar change in the near future.

Patients and Methods

In 1999, the conventional chest radiographic equipment in our department was replaced by a storage phosphor-based digital system (FCR 9501HQ, and FCR 9000HQ, Fuji, Japan). Since our department is participating in a screening project that includes an annual chest radiograph, we had a unique opportunity to evaluate and compare chest radiographs obtained with both techniques within a 1 year period in a relatively large population of "healthy" patients.

Two experienced thoracic radiologists (J.R. and I.G.) retrospectively evaluated 140 pairs of posteroanterior chest radiographs of 140 sequential subjects who obtained their chest radiographs as part of their annual screening tests. Conventional films were obtained using 125 kVp and 12 mAs. Digital films were obtained using 135kVp, and the mAs was regulated by an automatic phototimer. Patients with a history of thoracic surgery or cardiac or pulmonary disease were excluded from the study. The study group comprised 119 men and 21 women, with a mean age of 52.1 years (range 23–86 years). Digital films

PACS = picture archiving and communication system were printed (25.7 x 36.4 cm vs. 35.0 x 43.0 cm for conventional films). Each pair of radiographs included one conventional and one storage phosphor-based digital film, obtained within an interval period of 1 year. The conventional and digital films were evaluated in separate sessions independently by each radiologist during 1 month to avoid bias. Radiologists were blinded to any clinical history. The visibility of the following 12 anatomic landmarks was assessed: left oblique fissure, right oblique fissure, horizontal fissure, carina, main bronchi in left upper lobe, left lower lobe and right upper lobe, intermediate bronchus, anterior and posterior junctional lines, vessels behind the heart, and vessels behind the diaphragm. The visibility of each anatomic structure was evaluated by a 3-grade scale as follows: 1 = structure cannot be recognized, 2 = partial visibility, 3 = good visibility. In addition, the observers assessed their subjective overall impression of image quality as follows: 1 = intermediate, 2 = good, 3 = excellent.

Inter-observer agreement between the two radiologists was assessed for conventional and digital films with the kappa coefficient, which was characterized as follows: values less than 0.0 = "poor" agreement, 0.0–0.2 = "slight" agreement beyond chance, 0.21–0.4 = "fair" agreement, 0.41–0.60 = "moderate" agreement, 0.61–0.80 = "substantial" agreement, and 0.81–1.00 = "almost perfect" agreement [8].

Results

Results of visibility scoring for each of the reviewer are summarized in Tables 1 and 2. For both reviewers, the visibility of the carina, left lower lobe bronchus, bronchus intermedius, anterior junctional line, and blood vessels behind the diaphragm and behind the heart was significantly better on the digital films ($P < 0.05$). The inter-observer agreement (kappa) for digital and conventional radiographs is summarized on Table 3. The agreement between the two radiologists was higher on digital films for the right oblique fissure, anterior junctional line, and for visibility of vessels behind the diaphragm.

Table 1. Visibility scoring of observer No. 1 for each anatomic landmark using digital and conventional chest X-ray

	Digital film grading*			Conventional film grading*			
Anatomic structure	1	2	3	1	2	3	Statistical significance
Fissures							
Left oblique	102	24	14	109	15	16	NS
Right oblique	125	9	6	123	8	9	NS
Minor	77	24	39	76	23	41	NS
Carina	9	35	96	19	61	60	<0.001
Bronchi							
Left upper lobe	43	20	77	48	26	66	NS
Left lower lobe	6	11	123	8	40	92	<0.001
Right upper lobe	60	36	44	61	39	40	NS
Intermedius	7	33	100	12	59	69	<0.001
Junctional lines							
Anterior	101	21	18	117	16	7	<0.05
Posterior	54	35	51	58	30	52	NS
Blood vessels							
Behind diaphragm	5	49	86	29	67	44	<0.001
Behind heart	0	2	138	0	36	104	<0.001
General impression	0	17	123	0	66	74	<0.001

* Visibility scale: 1 = structure cannot be recognized, 2 = partial visibility, 3 = good visibility.

Table 2. Visibility scoring of observer No. 2 for each anatomic landmark using digital and conventional chest X-ray

	Digital film grading*			Conventional film grading*			
Anatomic structure	1	2	3	1	2	3	Statistical significance
Fissures							
Left oblique	99	26	15	108	20	12	NS
Right oblique	125	9	6	126	11	3	NS
Minor	77	23	40	74	28	38	NS
Carina	1	19	120	23	69	48	<0.001
Bronchi							
Left upper lobe	31	37	72	30	56	54	<0.05
Left lower lobe	13	49	78	32	57	51	<0.001
Right upper lobe	47	32	61	52	28	60	NS
Intermedius	4	19	117	9	33	98	<0.01
Junctional lines							
Anterior	93	27	20	124	14	2	<0.001
Posterior	73	21	46	97	23	20	<0.001
Blood vessels							
Behind diaphragm	6	24	110	72	44	24	<0.001
Behind heart	0	4	136	11	69	60	<0.001
General impression	0	19	121	4	105	31	<0.001

* Visibility scale: 1 = structure cannot be recognized, 2 = partial visibility, 3 = good visibility.

Table 3. Inter-observer agreement (kappa) for digital and conventional radiographs

Anatomic structure	Digital films	Conventional films
Fissures		
Left oblique	0.37	0.43
Right oblique	0.35	0.19
Minor	0.52	0.54
Carina	0.32	0.32
Bronchi		
Left upper lobe	0.33	0.24
Left lower lobe	0.13	0.15
Right upper lobe	0.21	0.22
Intermedius	0.27	0.21
Junctional lines		
Anterior	0.28	0.13
Posterior	0.30	0.27
Blood vessels		
Behind diaphragm	0.36	0.16
Behind heart	0.28	0.22
General impression	0.219	0.169

Discussion

One of the most important advantages of digital radiography is the wide exposure latitude, which is 10 to 100 times greater than the widest dynamic range of screen-film systems. During digital image processing, the systems automatically determine the range of clinically appropriate gray levels and produce an image within that range. As a result, the final image is virtually independent of absolute X-ray exposure levels. Another major advantage of digital radiography is related to the fact that it produces what are essentially electronic images; as a result, an image may be transmitted to any location, displayed at multiple sites simultaneously, and efficiently archived for later reference. Given the rapid development of computer technology and storage capacity, PACS-integrated hospital information systems will become more important in clinical practice in the near future. Digital chest radiography will play an important role in this evolution because chest X-rays represent about 25% of all diagnostic radiography examinations [1] and are often obtained repeatedly for the follow-up of patients. In most medical imaging departments the first step in digital chest radiography is obtained by the introduction of storage phosphor plates because of their compatibility with existing radiography equipment. One of the more important clinical questions relating to digital radiography is that of minimum spatial resolution requirements, that is, how small must each pixel be in order to provide diagnostic image quality comparable to that of conventional film display? The current weight of opinion favors a pixel size of no larger than 0.2 mm for diagnosis; this corresponds to a matrix size of 2,000 x 2,000 for a 40 x 40 cm field – the area required for imaging the adult chest [3,9]. A similar resolution was used for digital chest X-ray in the present study. On the other hand, in contrast to conventional chest X-ray systems, which have a non-linear response over a limited range of exposures, the receptor plate in digital systems has a linear photoluminescence/dose response over a range of more than four orders of magnitude [3,4]. As a consequence, previous studies based on developmental prototypes of storage phosphor-based images [5–7] found them superior to conventional film radiographs for visualization of the mediastinum, retrocardiac region, and sub-diaphragmatic recesses, and equivalent or superior to conventional film in the detection and evaluation of pulmonary nodules and opacities. Our purpose was to assess whether those advantages really exist in a commercial digital system used in a clinical setup. The transfer time in our department between the old conventional chest X-ray and the new digital system, combined with the possibility to evaluate yearly sequential chest X-rays of patients with no evidence of any lung disease (as part of their annual screening program), offered us a golden opportunity to compare chest X-rays of the same patient taken with both systems within a relatively short period.

Our results with digital phosphor-based chest X-rays are in full agreement with the above previous studies, suggesting a better visibility of anatomic landmarks behind the heart, mediastinum or hemidiaphragm. The visibility of those areas was significantly superior on digital films for both independent reviewers. In addition, the overall impression of image quality was significantly higher for digital as compared to conventional chest films. This suggests a better visibility of pathologic lesions (nodules, tumors, consolidations, etc.), particularly if projected over those anatomic areas when using digital films as compared to conventional. In addition, we found an improved inter-observer agreement for digital when compared to conventional radiographs, mainly for some of the anatomic structures projected over the diaphragm or the mediastinum.

The influence of the different technical parameters (mAs and kVp) that were used for each series of films could not be measured or compared due to the overall differences in technology.

A disadvantage in our study was that due to economic reasons we used smaller prints of digital films in comparison to the conventional ones. Nevertheless, we believe that the use of larger prints of digital films would further emphasize the advantage of this technique when compared to conventional ones.

Conclusions

With the current storage phosphor-based digital systems, the visibility of anatomic landmarks behind the heart, mediastinum, hemidiaphragms and hilae is superior when compared with the conventional X-ray systems. This suggests that pathologic processes such as pulmonary nodules, masses or consolidations projected especially over those structures may be more easily and reliably depicted on digital than on conventional chest X-rays.

Acknowledgments. We thank the technical staff of our department, especially Joseph Vered, Arie Moskovitz and Dani Bashi, for their cooperation and help.

References

1. United Nations Committee on the Effects of Atomic Radiation. Sources and effects of ionizing radiation. Vol 1. Sources, annex D. Medical radiation exposure. New York: United Nations, 2000:355.
2. Garmer M, Hennigs SP, Jager HJ, et al. Digital radiography versus conventional radiography in chest imaging: diagnostic performance of a large-area silicon flat-panel detector in a clinical CT-controlled study. *Am J Roentgenol* 2000;174:75–80.
3. Ravin CE, Chotas HG. Chest radiography. *Radiology* 1997;204:593–600.
4. Rong XJ, Shaw CC, Liu X, Lemacks MR, Thompson SK. Comparison of an amorphous silicon/cesium iodide flat-panel digital chest radiography system with screen/film and computed radiography systems: a contrast-detail phantom study. *Med Phys* 2000;28:2328–35.
5. Schaefer CM, Greene R, Hall DA, et al. Mediastinal abnormalities: detection with storage phosphor digital radiography. *Radiology* 1991;178:169–73.
6. Schaefer CM, Greene R, Oestmann JW, et al. Digital storage phosphor imaging versus conventional film radiography in CT-documented chest disease. *Radiology* 1990;174:207–10.
7. Cox GG, Cook LT, McMillan JH, Rosenthal SJ, Dwyer SJ 3rd. Chest radiography: comparison of high-resolution digital displays with conventional and digital film. *Radiology* 1990;176:771–6.
8. Dawson-Saunders D, Trapp RG. Basic and Clinical Biostatistics. San Mateo, CA: Appleton & Lange, 1990:58–9.
9. Fraser RG, Sanders C, Barnes GT, et al. Digital imaging of the chest. *Radiology* 1989;171:297–307.

Correspondence: Dr. E. Konen, Dept. of Diagnositic Imaging, Sheba Medical Center, Tel Hashomer 52621, Israel.
Phone: (972-3) 530-2530
Fax: (972-3) 535-7315
email: konen@zahav.net.il