Detectability of Mediastinal Lines on Chest Radiograph in Adult Japanese Population: Conventional versus digital chest radiograph

A.K.M. Anisuzzaman Khan, Junpei Ikezoe, Noriyuki Takeuchi, Shigeyuki Yoshida, Takeshi Johkoh, Kazuya Ichikado, Jun Arisawa and Hironobu Nakamura

Department of Radiology, Osaka University Medical School

成人日本人における胸部X線像上の縦隔線の検討

A. K. M. アニスッザマン・カーン，
池添　潤平，竹内　規之，吉田　重幸，
上甲　剛，一門　和哉，
有澤　淳，中村　仁信

健常成人における縦隔線と他の解剖学的指標の出現頻度と，conventional X線像とdigital X線における縦隔線と他の解剖学的指標の描出能の差異を評価するために，健常成人のconventional X線像とdigital X線の各200例を検討した．conventional X線像の撮像にはDupoint社製C-4Dフィルムを用い，グリッド比12：1，管電圧130kVp，感度100で撮像された．digital X線像は解像度4000×4000のFCR9000を用いて撮像し，縦隔構造にはDR圧縮が施された．digital X線像においては，前接合線が29%，後接合線が57%，右気管傍線が94%，奇静脈食道線が81%，左椎体傍線が50%，横隔膜下の血管影が59%で完全に描出された．これらの縦隔線と解剖学的指標はdigial X線像においてconventional X線像と比べて優位に良好に描出された($P < 0.01$)．縦隔線や横隔膜下の血管影の描出はconventional X線像よりもdigital X線像の方が優れていると考えられた．

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大阪大学医学部放射線医学教室

Introduction

Although several imaging modalities such as computed tomography (CT) and magnetic resonance imaging (MRI) have been introduced for the diagnosis of chest diseases, chest radiography is still considered to be the most important examination. Plain chest radiography is the imaging examination of first choice in patients with chest disease, because it is easy to perform and inexpensive, and because it provides information as to the overall state of the chest. Thus, chest radiography is the fundamental diagnostic tool in patients with suspected pulmonary disease.

In interpreting chest radiographs, one of the most important points is recognizing the mediastinal lines and certain anatomical landmarks such as fissure lines. There are many reports addressing the formation, detectability or significance in different clinical categories of mediastinal lines and other anatomical landmarks[1)-17)]. When one of the mediastinal lines cannot be recognized on a chest radiograph with good penetration, the presence of mediastinal abnormalities or parenchymal lung abnormalities adjacent to the mediastinum is strongly suggested. Although there are many reports regarding the detectability of mediastinal lines or anatomical landmarks observed on chest radiographs among the normal adult population in Western countries, to the best of our knowledge, there are no such reports regarding the normal adult Japanese population.

Several experimental studies with a variety of different techniques of digital chest radiography have been carried out[18)-23)], and digital chest imaging was recently introduced into clinical practice. One of the advantages of digital chest radiography is the capacity for post-processing techniques such as high-frequency edge enhancement. Dynamic range control (DRC) processing is another of the advanced post-processing techniques for digital chest imaging[24)].

In this study, we evaluated the detectability on conventional screen film chest radiographs obtained in normal adult Japanese patients of five main mediastinal lines (the anterior mediastinal line, posterior mediastinal line, right paratracheal

stripe, azygoesophageal recess, and left paraspinal line) and four anatomic landmarks (the major and minor fissures, pulmonary vasculature overlapping the right hemidiaphragm, and apical opacity). The detectability of each was compared with that in digital chest imaging with DRC.

Materials and Methods

A total of 400 posteroanterior chest radiographs (200 conventional and 200 digital radiographs) were studied as the main materials in this study. The conventional chest radiographs were obtained with Dupont C-4D film, a BF-III screen (Kyokko Optonics), and 12 :1 grid at 130 kVp (relative system speed, 100). Digital chest images were obtained with FCR (Fuji Computed Radiography, model No. 9000; 0.1 mm pixel size and 10-bit depth), using the same exposure conditions as those in the conventional chest radiography. FCR images were displayed on the hard copies in default mode, followed by the application of dynamic range control processing. All chest images had been obtained in the erect position during full inspiration.

Since 1993, only digital radiographs have been used for diagnostic purposes at our hospital. The conventional and digital radiographs examined in this study were selected by two experienced radiologists from the hospital file records, and all of the films had been obtained between 1990 and 1993 at our hospital. The patients ranged in age from 21 to 80 years (mean, 49.2 years), and for each modality images from 100 men and 100 women were selected. The patients were grouped into age decades from the 20's to 70's, and equal numbers of films were included for all the age groups. To our knowledge there are no established criteria for the selection of films for a study of this kind. Therefore we employed some of the criteria adopted for film selection in previous studies[6),17)]. All radiographs included in this study were deemed to show normal findings, and the review of the patient's clinical records revealed no evidence of chest abnormality based on history, symptoms and complaints, or follow-up findings. None of the films revealed any evidence of pleural effusion, pleural thickening, scoliosis, asymmetry of the thorax, mediastinal shift, regional loss of volume or scar of the lung parenchyma, and nothing that could conceivably alter the normal appearance of the lung-mediastinal interface and anatomical landmarks. Some radiographs with minor old tuberculous changes were included in this study.

The following mediastinal lines and several anatomical landmarks were evaluated: the anterior junctional line[1)-5)], posterior junctional line[1),2),6),7)], right paratracheal stripe[1),8)], azygoesophageal recess[9)-11)], left paraspinal line[1),2),12),13)], major fissure line and minor fissure line[14)-16)], pulmonary vessels in the right posterior lung base overlapping the right hemidiaphragm, and apical opacity[17)].

When the entirety of the mediastinal line was well visualized it was deemed to be "visualized" (Fig.1 and 2). When a mediastinal line was detected partially or not detected at all, it was classified as "non-visualized". For the assessment of minor fissure, when the fissure was detected extending from the lateral chest wall to the right interlobar pulmonary artery, it was categorized as "visualized", but when it was only partially detected or was not detected, it was categorized as "non-visualized". In the assessment of the pulmonary vessels in the right posterior lung base, an imaginary line between the right costophrenic and cardiophrenic angles was employed. When the vascular shadows were detected through the right hemidiaphragm passing inferiorly beyond the imaginary line, the vessels were deemed to be "visualized" (Fig.3). When the vascular shadows were detected through the right hemidiaphragm superior to the imaginary line, or were not

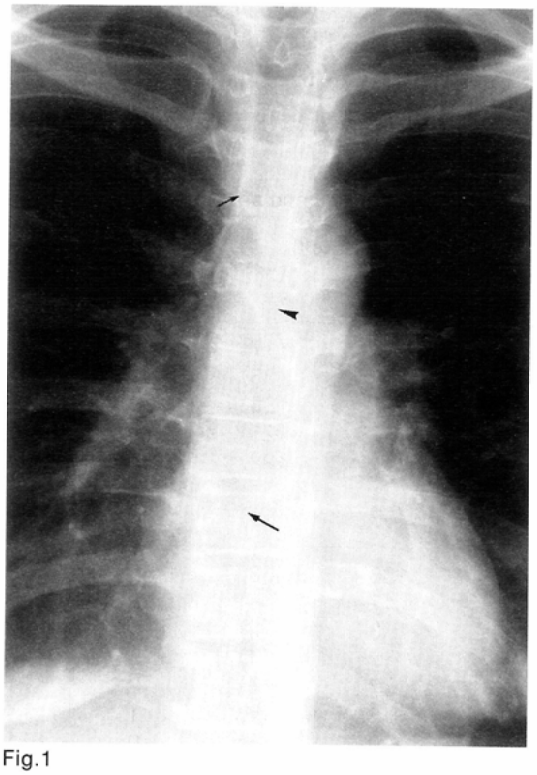

Fig.1

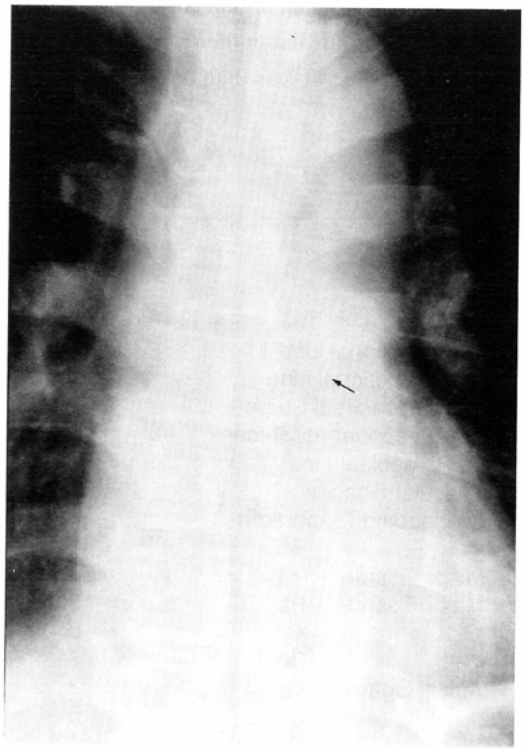

Fig.2

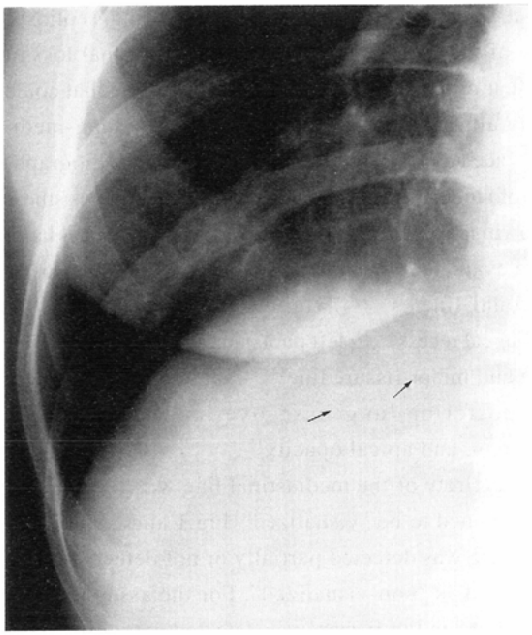

Fig.3

found inferior to the contour of the right hemidiaphragm, they were classified as "non-visualized". The presence of apical opacity[17] and major fissure on the right, left, or both sides was noted.

The mediastinal lines and anatomical landmarks were examined by three radiologists who evaluated whether each of these anatomical features was well visualized. In the few instances in which there was some difference of opinion among or between radiologists as to the detectability of the mediastinal lines, the final determination was made by mutual agreement. The Chi-square test was used to analyze differences between the detectability of anatomical features on conventional radiographs and that on digital chest radiographs, both for the entire patient group and in the separate male and female subgroups. A p value of less than 0.05 was regarded as statistically significant.

Results

1. Mediastinal lines

The percentages of conventional radiographs showing complete visualization of the anterior junctional line, posterior junctional line, right paratracheal stripe, azygoesophageal recess and left paraspinal line were 17%, 35%, 88%, 26%, and 22%, respectively, and those for the digital chest images were 29%, 57%, 94%, 81%, and 50%, respectively (Table 1). The visualization of all mediastinal lines except the right paratracheal stripe was significantly better on digital chest radiographs than on conventional chest radiographs ($p < 0.01$) (Table 2). There was no significant gender-related difference in the detectability of mediastinal lines on either the digital radiographs (Table 3) or conventional radiographs (Table 4).

2. Other anatomical landmarks

The rate of detectability on conventional chest radiographs of vascular shadow in the right posterior basal lung overlapping the right hemidiaphragm, and of minor fissure were 4 % and 68% respectively. Major fissure was visualized on the right side, left side or both sides in 9%, 2%, and 4% of the conventional radiographs, respectively, and apical opacity was visualized in 4%, 7% and 5%, respectively.

On the digital radiographs, the rates of detectability of vascular shadow in the right basal lung and of minor fissure were 59% and 52%, respectively. The major fissure was visualized on the right side, left side and both sides on 7%, 2% and 3%, respectively, and apical opacity on 2%, 3% and 1 %, respectively. There were significant differences between conventional radiographs and digital radiographs in the detectability of the pulmonary vasculature through the right hemidiaphragm and the apical opacity. The pulmonary vasculature overlapping the right hemidiaphragm was better visualized on digital radiographs ($p < 0.01$), but apical opacity was better observed on conventional radiographs ($p < 0.01$).

Table 1 Detectability of mediastinal lines and anatomical landmarks

		Conventional Chest Radiograph				Digital Chest Radiograph			
		Male n = 100	Female n = 100	Total n = 200	(%)	Male n = 100	Female n = 100	Total n = 200	(%)
Ant. Junctional Line		20	14	34	(17)	24	34	58	(29)
Post. Junctional Line		40	30	70	(35)	55	59	114	(57)
Rt. Paratracheal Stripe		89	87	176	(88)	92	95	187	(94)
Azygoesophageal Recess		32	20	52	(26)	77	84	161	(81)
Lt. Paraspinal Line		19	25	44	(22)	51	49	100	(50)
Vascular Shadow overlapping Diaphragm		6	1	7	(4)	60	57	117	(59)
Minor Fissure		76	60	136	(68)	56	48	104	(52)
Major Fissure	Rt.	12	5	17	(9)	9	5	14	(7)
	Lt.	0	3	3	(2)	0	3	3	(2)
	Both	3	4	7	(4)	3	3	6	(3)
Apical Opacity	Rt	2	5	7	(4)	2	1	3	(2)
	Lt.	5	8	13	(7)	1	4	5	(3)
	Both	4	6	10	(5)	0	1	1	(1)

Table 2 Summary of the detectability of mediastinal lines and anatomic landmarks

		Conventional chest radiograph (%)	Digital chest radiograph (%)	Reported data (%)
Anterior Mediastinal Line*		17	29	20-25
Posterior Mediastinal Line*		35	57	40
Right Paratracheal Stripe		88	94	63
Azygoesophageal Recess*		26	81	60-70
Left Paraspinal Line*		22	50	---
Pulmonary Vessels overapped by Diaphragm*		4	59	---
Minor Fissure		68	52	66
Major Fissure	Rt.	13	10	---
	Lt.	6	5	---
Apical Opacity	Rt.	9	3	14
	Lt.*	12	4	17

*Differnce between conventional and digital chest radiograph was statistically significant ($p < 0.01$)

3. Detectability of each mediastinal line in each age group

Digital chest radiography revealed a clear tendency towards increased detectability of the anterior junctional line and left paraspinal line with the age of the patients. Detectability of the anterior junctional line conversely decreased with the age of the patients. On the other hand, that of the left paraspinal line showed a direct increase with age, whereas that of the other mediastinal lines showed no marked change related to age.

On conventional chest radiographs, we observed no age-related change in the detectability of mediastinal lines.

Discussion

The recognition of mediastinal lines and other anatomical landmarks is extremely important in the interpretation of chest radiographs. Mach band effect is recognized as a form of visual edge enhancement produced by physiological optical processing[25]. There are diverse opinions regarding mediastinal lines such as the left paraspinal line, which is considered to be produced either as a Mach band effect[12] or due to the spatial pattern of the optical densities in the region of the left thoracic paraspinal line rather than the tissue composition[13]. When one cannot recognize the mediastinal lines, which normally should be recognized on a plain chest radiograph, the possibility is suggested of the presence of some pathology in the mediastinum or lung parenchyma adjacent to the mediastinum. For example, obliteration of the azygoesophageal recess usually indicates the presence of some pathological process in the subcarinal region[26]. On the other hand, in some instances, obliteration of a mediastinal line may reflect the specific status of the patient. For example, obliteration of the left border of the descending aorta is found in patients with pectus excavatum[27].

However, it is well known that not all mediastinal lines are always recognized on chest radiographs, and it is therefore important to establish how often one might expect to recognize the normal mediastinal lines on chest radiographs in normal adult patients. The detectability of the mediastinal lines and other anatomic landmarks has already been reported in the English literature (Table 2). The reported detectability on chest radiographs is 20-25% for the anterior junctional line[5], 40% for the posterior junctional line[6], 94% for the right paratracheal stripe[8], and 60-70% for the azygoesophageal recess[26]. According to our results, the detectability of these mediastinal lines was 17%, 35%, 88%, and 22%, respectively. The English literature offers no detailed data regarding the left paraspinal line on conventional chest radiographs. Among

Table 3 Detectability of mediastinal lines related to the age of the patients with digital chest radiograph

Patient's age		21-30	31-40	41-50	51-60	60-70	71-80
Anterior Mediastinal Line		53 (%)	29 (%)	35 (%)	9 (%)	14 (%)	26 (%)
Posterior Mediastinal Line		66	66	53	58	48	55
Right Paratracheal Stripe		97	95	91	91	83	100
Azygoesophageal Recess		81	94	77	79	71	87
Left Paraspinal Line		28	46	56	64	60	64
Pulmonary Vessels overapping Diaphragm		61	60	61	64	59	50
Minor Fissure		59	48	56	54	55	42
Major Fissure	Rt.	13	3	12	19	6	16
	Lt	3	6	6	9	0	3
Apical Opacity	Rt.	3	0	0	6	0	3
	Lt.	8	3	3	0	3	7

Table 4 Detectability of mediastinal lines related to the age of the patients with conventional chest radiograph

Patient's age		21-30	31-40	41-50	51-60	60-70	71-80
Anterior Mediastinal Line		28 (%)	24 (%)	12 (%)	18 (%)	18 (%)	3 (%)
Posterior Mediastinal Line		43	46	24	30	20	44
Right Paratracheal Stripe		100	94	84	82	86	81
Azygoesophageal Recess		40	24	15	27	33	17
Left Paraspinal Line		25	15	22	33	30	6
Pulmonary Vessels overapping Diaphragm		3	0	3	3	6	10
Minor Fissure		77	70	77	65	73	50
Major Fissure	Rt.	11	18	10	17	9	11
	Lt	3	6	0	6	3	3
Apical Opacity	Rt.	11	15	7	6	3	6
	Lt.	9	21	10	9	9	6

other anatomic landmarks, the minor fissure has been reported to be found at a frequency of 66%[1], and the apical opacity at of 14% on the right side and 17% on the left[17]. In our study, the minor fissure was observed in 68% of the conventional radiographs examined, and apical opacity was found in 4% on the right and 7% on the left side. In comparing the detectability of mediastinal lines and other anatomic landmarks observed in our study with those reported in the literature, we noted that in our study the azygoesophageal recess and apical opacity were less frequently observed on the conventional radiographs. Although we are not sure of the reason for the lower frequency, we can suggest three possiblities. The first possibility is a difference in the chest radiographs evaluated in the reported studies and in our study. Conventional chest films and screens differ and may be, for example, of wide latitude type, high contrast type, or standard type. When a wide latitude-type radiograph and screen are used, the azygoesophageal recess may be better visualized than with high contrast films are used. Of course, the exposure conditions including increased exposure voltage and dose also increase the visualization of some mediastinal lines[28] and decrease the visibility of very small nodules or linear structures[29]. In the previous reports regarding the detectability of mediastinal lines, no detailed information is given concerning the film, screen, and exposure conditions. The second possibility is that the criteria for visualization of the mediastinal line may differ in our study and in the reported studies. In our study a mediastinal line was deemed visualized when it was visible in its entirety. Thus, our criteria for visualization might have been extremely rigorous. The third possibility may be a difference in the patients' age in the reported studies and in ours. In this study we found that the detectability of the left paraspinal line on conventional radiographs increased proportionately with the patients' age.

Our comparison of conventional and digital chest radiographs revealed that all mediastinal lines except the right paratracheal stripe were significantly better visualized on the digital radiographs than on the conventional ones. The superiority of digital radiography may be due to the image processing of digital images. These digital images were first processed in default mode which allowed approximation of the appearance of a conventional radiograph, so that the density and contrast of the digital images were closely matched to those of the conventional chest radiographs. The images were processed with a sigmoid, low-contrast Hurter-Driffield curve and with slight edge enhancement at low frequencies. Following this, dynamic range control processing was applied to the default mode image. The dynamic range control processing used is algorithmically similar to the conventional unsharp mask technique. This technique was applied selectively to low-density regions such as the mediastinum and lung parenchyma overlapping the diaphragm and heart. The threshold and parametric values adopted in this technique were the same for all patients and were applied automatically. Our preliminary study suggested that dynamic range control processing is useful in the display of digital chest radiographs and in the detection of normal mediastinal structures and normal and abnormal lung lesions overlapping the heart and diaphragm[24]. Mediastinal diseases are more easily recognized on digital images following post-processing with edge enhancement at high frequencies than on conventional radiographs[30].

The detectability of two mediastinal lines showed clear age-related change. The detectability of the anterior junctional line decreased with age, whereas that of the left paraspinal line increased. With age, elongation and/or dilatation of the aorta and its branches may advance, resulting in greater protrusion of the descending aorta into the left lung, and resulting in buckling of the branches of the aorta. This might be the main reason for the observed age-related changes.

The pulmonary vasculature through the right hemidiaphragm was better visualized on the digital radiographs than on the conventional ones. We also attribute this to the post-processing of digital images. In contrast, the apical opacities were better visualized on conventional radiographs. Although we are

unsure as to why, one reason may be the different characteristics of the detectors themselves. Furthermore, the contrast of the lung field on conventional radiographs may differ from that on digital radiographs. For the depiction of subtle air space disease process and ground glass opacities, conventional screen-film chest radiographs might be more suitable than storage phosphor radiographs[31].

We are inclined to attribute the differences in the detectability of mediastinal lines and other anatomic landmarks between our study and other reported studies not to differences in race, but to differences in technical factors such as exposure voltage[28),29)], film, screen, and use of a filter.

In conclusion, for the detection of normal mediastinal lines and visualization of posterior basal pulmonary vessels overlapping the right hemidiaphragm, digital radiographs are superior to conventional radiographs.

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