た。その結果が妥当なことは、アナログの標準で画像処理 A,B,C,D を施された被分類写真を密度分類した時も、やはりCの結果がもっとも、通常の方法の結果と酷似したことで裏付けられた。本研究班が現在のCR, DRで日本の標準を再構築し、それがアナログまたはデジタル化された ILO 標準とどの程度トレーサビィテイがあるか確認する時にも、このような至適画像処理の事前の設定が必要である。その際、処理Cの画質が推奨できる。但し、この実験で用いられた被分類用写真はアナログ写真をデジタイズしたものであった。FCR で直接撮影されたデジタル画像に対しては処理Fが至適であった。この結果はデジタル画像(CR,DR)が今後じん肺診断に活用される時の至適処理条件を検討付ける時に役立つと思われる。

第二のポイントは標準写真と被分類写真の画像サイズの問題である。本PXQ委員会の研究によれば標準と被分類写真が同じサイズであればそれらが縮小されたものであっても通常の方法と同等の密度分類が再現できる。CR,DR の普及が進むにつれ、モニター診断(ソフトコピー)によるじん肺診断が日常化する可能性があるが、その時の回答が本レビューにより示唆されたと考える。第三のポイントはじん肺画像のデジタル化が日常化した時、じん肺診断用コンピュータ支援診断システム(CAD)を応用し、CAD によるじん肺分類の定量化を図る可能性があることである。

1.3のレビューでは言及しなかったが、PXQ委員会はじん肺診断用 CAD の開発も検討した。[11,14]図12にその一端を示す。名古屋大学鳥脇研究室が開発した CAD が 1908 年版 ILO 標準に存在する粒状影：r の数および r が占める面積を算出し、ILO実験で得られた 2.1.2 1)の医師の密度分類(mid-category)との回帰を求めた結果である。観測値は1,2,3型の3点のみだが医師の密度分類(12階尺度)と良好な対応関係が認められ、CAD によるじん肺密度分類の可能性が示唆された。

2. 標準関連の実験の方法と目的：過去から未来志向へ

ここでレビューした標準写真関連の代表的研究の実験方法および目的を総括すると以下のようになる。

① アナログ原寸大標準写真対アナログ原寸大被分類写真(Jacobsen、日下、PXQ)
② アナログ原寸大 QUAD 標準写真対アナログ原寸大被分類写真(Jacobsen)
③ アナログ原寸大標準写真対デジタル縮小被分類写真(アナログ原寸大をデジタイズして縮小したもの、FCR 画像)(PXQ)
④ デジタル縮小標準写真対デジタル縮小被分類写真(アナログ原寸大をデジタイズして縮小したもの、FCR 画像)(PXQ)

・ Jacobsen 論文は①、②の読影者内・間変動を比較評価、新標準の可能性を検討した。
・日下論文は①の被分類写真として日本の標準写真を対象とし、当該写真の日本の標準密度分類と英国読影者の密度分類結果を評価、ILO 標準に日本標準がどの程度準拠しているかトレーサビィテイを検討した。
・PXQ委員会は①、③、④の読影者間変動、読影者の密度分類対画像処理、画像サイズの影響の関係を比較評価、デジタル縮小写真と FCR の至適画像処理を検討およびデジタル ILO 縮小標準、デジタル労働省標準、FCR 画像に対して「元の写真ともっとも似ている」、「よく見える」画像処理を検討した。

・ 但し、「密度分類の継続性と一貫性の保持」をアウトカムとする。

今後検討すべき研究および実験として以下が考えられる。目的は上記レビューした文献と基本的同じである。但し、それらの目的が以下の実験で果たせるのか、この実験から何が得られるのか等現時点では吟味不十分である。考えられる項目を羅列しておく。

①デジタル原寸大 1980 年版 ILO（または QUAD）（ILO 作成）標準写真対デジタル原寸大被分類写真（村田班で収集中の CR,DR 画像）読影実験

アナログ原寸大 1980 年版 ILO（または QUAD）（ILO 作成）標準写真対デジタル原寸大被分類写真（村田班で収集中の CR,DR 画像）読影実験

②デジタル原寸大日本標準写真の作成

③デジタル原寸大日本標準写真対デジタル原寸大被分類写真（村田班で収集中の CR,DR 画像）読影実験

アナログ原寸大日本標準写真対デジタル原寸大被分類写真（村田班で収集中の CR,DR 画像）読影実験

④デジタル原寸大 ILO 標準写真（ILO 作成）対デジタル原寸大被分類写真（日本の標準写真）読影実験

アナログ原寸大 ILO 標準写真（ILO 作成）対デジタル原寸大被分類写真（日本の標準写真）読影実験

⑤境界写真を導入した場合（日本または ILO 構想）の効果：医師内・間変動を評価

⑥モニター診断への対応

結論

H19 年度村田班研究計画によれば、本研究班は 3 年間を目安にしてじん肺診断の参考となるデジタル症例写真集を作成することを課題としている。その次の課題は、その症例集を活用してデジタル画像の応用性を検証することになると思われる。本報から種々なことが示唆される。しかし、そのすべてを並行して行うことはできない。第一優先で取り組むべき課題は何か、その次は何か狙いを定めて、そのための準備を今からしておく必要がある。なぜなら、Jacobsen の実験に代表されるようにじん肺診断で新しいモダリテイの導入の有用性を検証するには、多大な費用と時間と空間（多数の施設・人の共同研究が基本）を要するからである。関係部署の代表からなるワーキンググループにより、費用の確保、実行方法、タイムスケジュール等、デジタル画像の応用性を検証するための具体的な次期中期計画の策定を提言したい。

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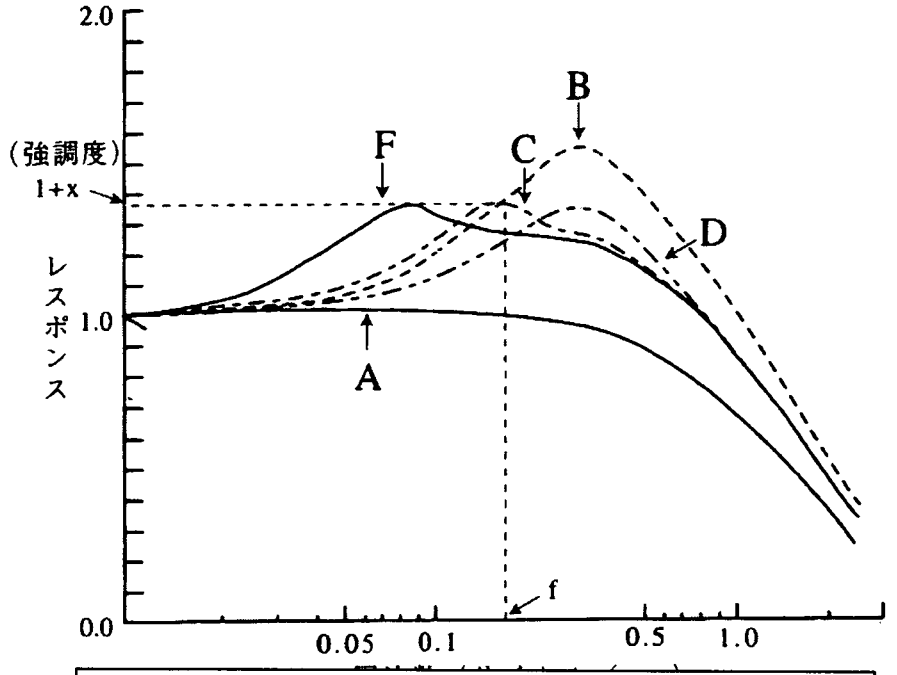


図１　検討されたFCRの画像処理の特性

表１　画質評価実験の結果

調査事項	ILO標準	労働省標準	FCR症例
元の写真に似ている処理	A，C	A，F	A，F
よく見える処理	C	C，F	C，F

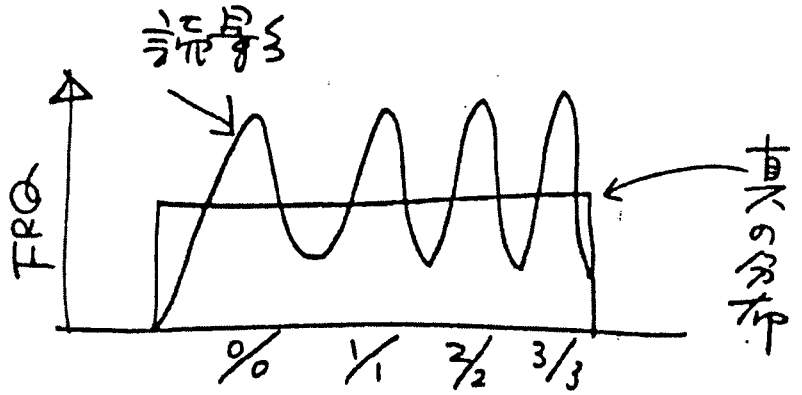


図２

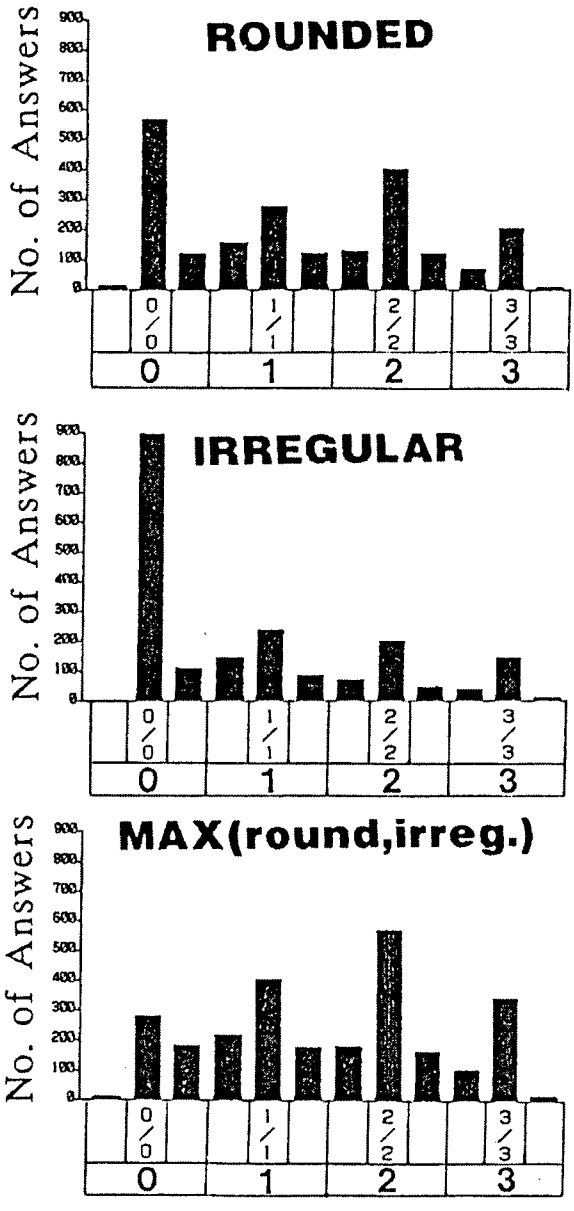

ROUNDED
IRREGULAR
MAX(round,irreg.)
No. of Answers
0/0
1/1
2/2
3/3
0
1
2
3
Profusion

図3

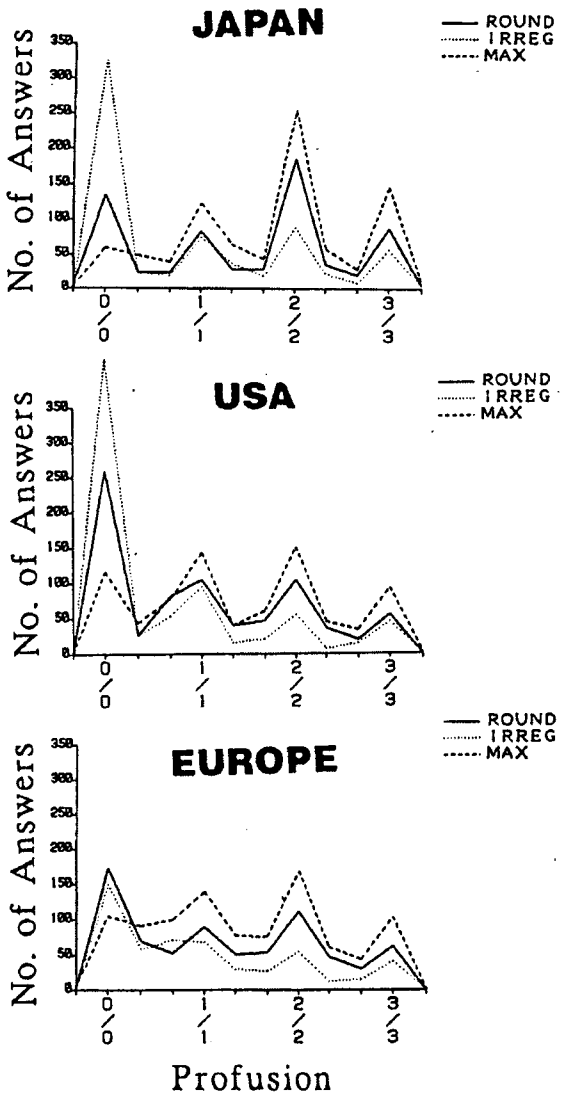

JAPAN
USA
EUROPE
ROUND
IRREG
MAX
No. of Answers
0/0
1/1
2/2
3/3
Profusion

図4

EXPERIMENT-1:

「Full-size ILO-films vs. Full-size test films」

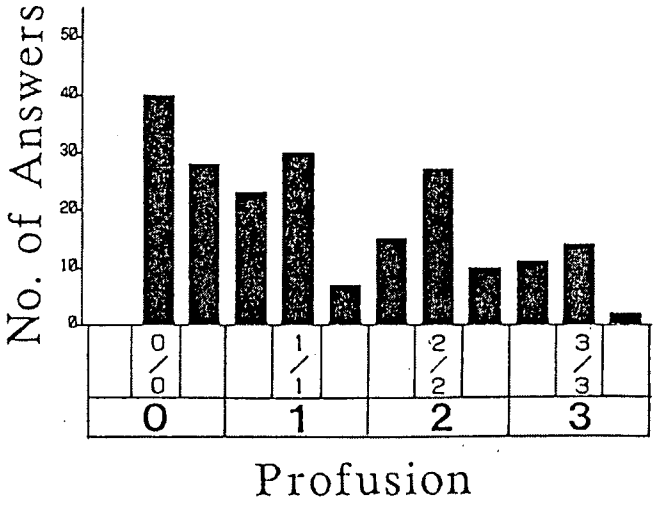


図5

EXPERIMENT-2

Reduced ILO films vs. reduced test films

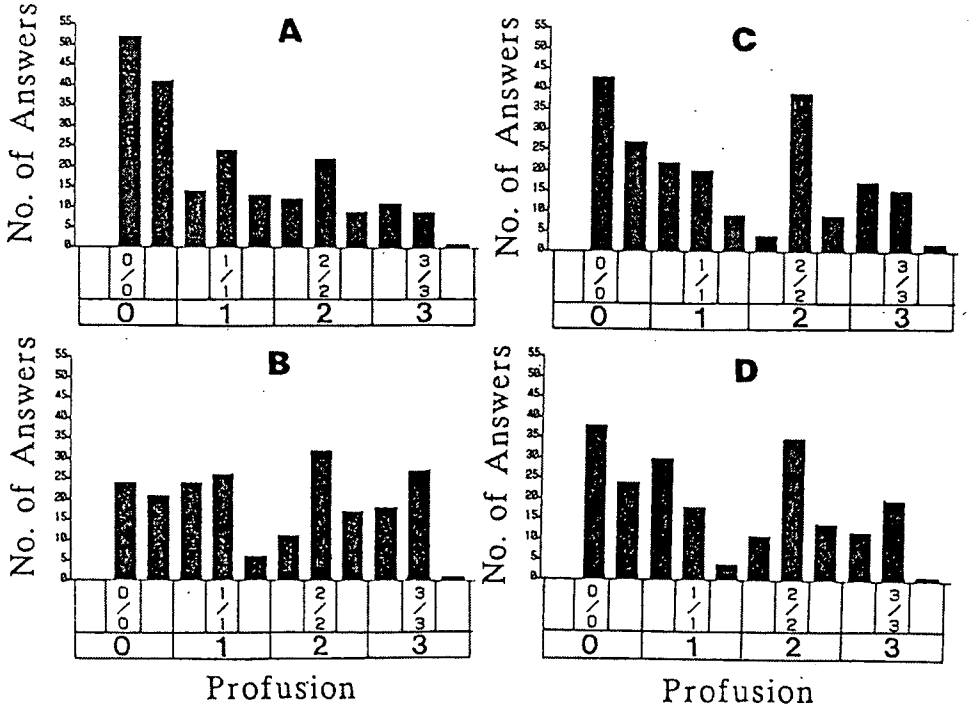
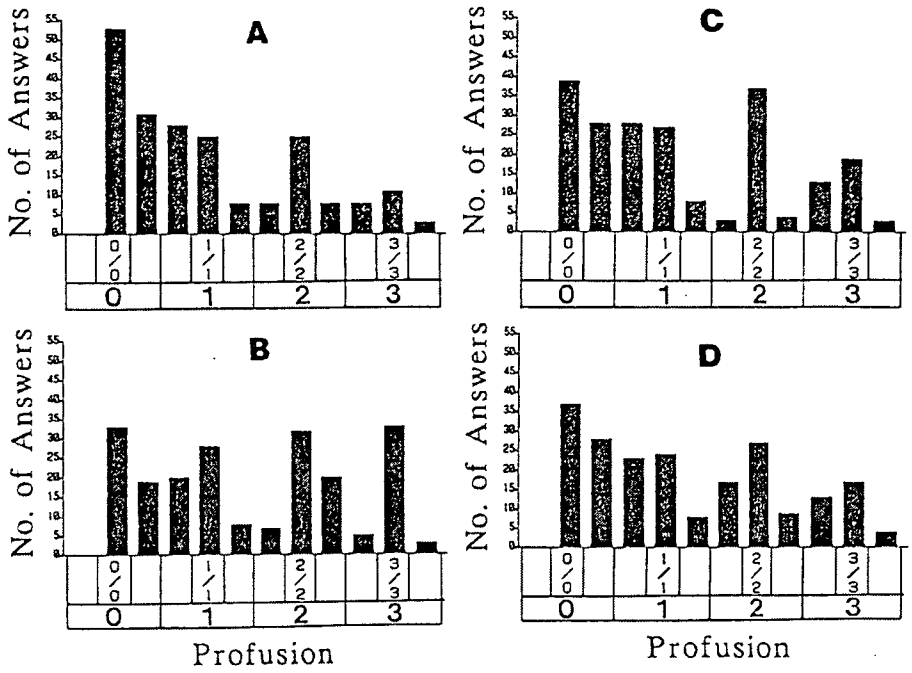


図6

EXPERIMENT-3

Full-size ILO films vs. reduced test films

図 7



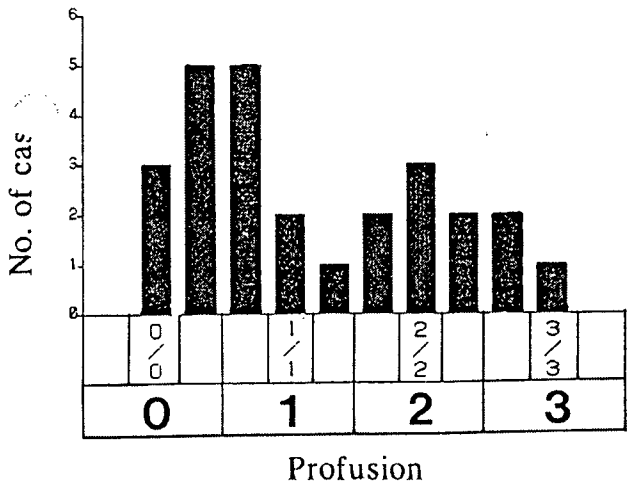


図 8

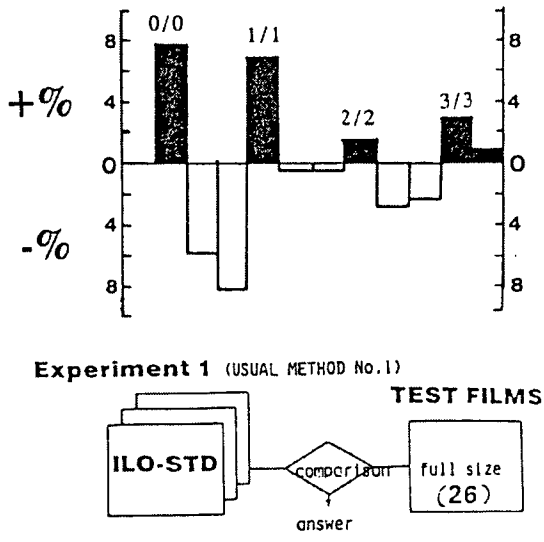


図 9

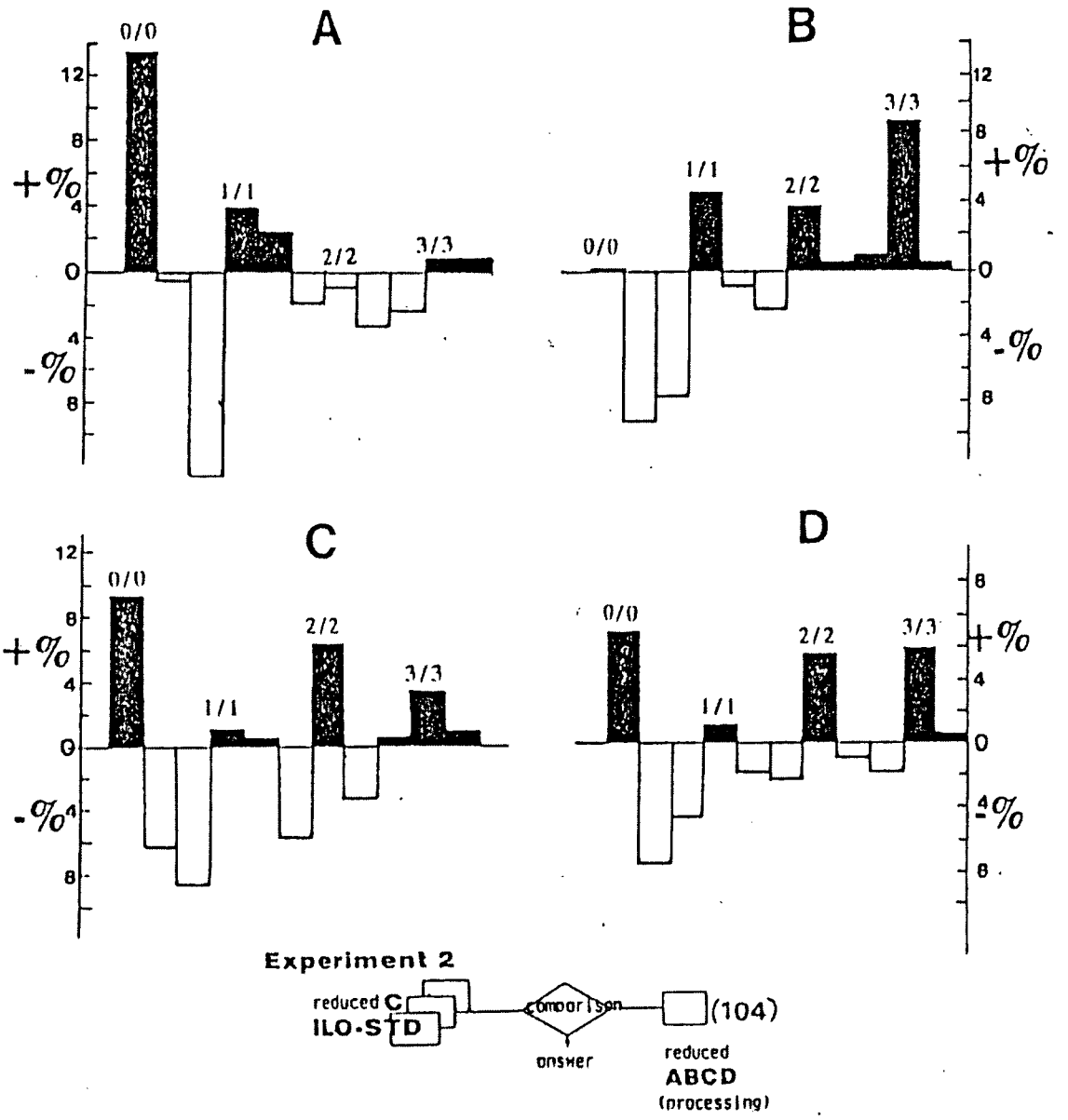

A
B
C
D
0/0
1/1
2/2
3/3
+%
-%
12
8
4
0
Experiment 2
reduced C
ILO-STD
comparison
answer
(104)
reduced
ABCD
(processing)

図１０

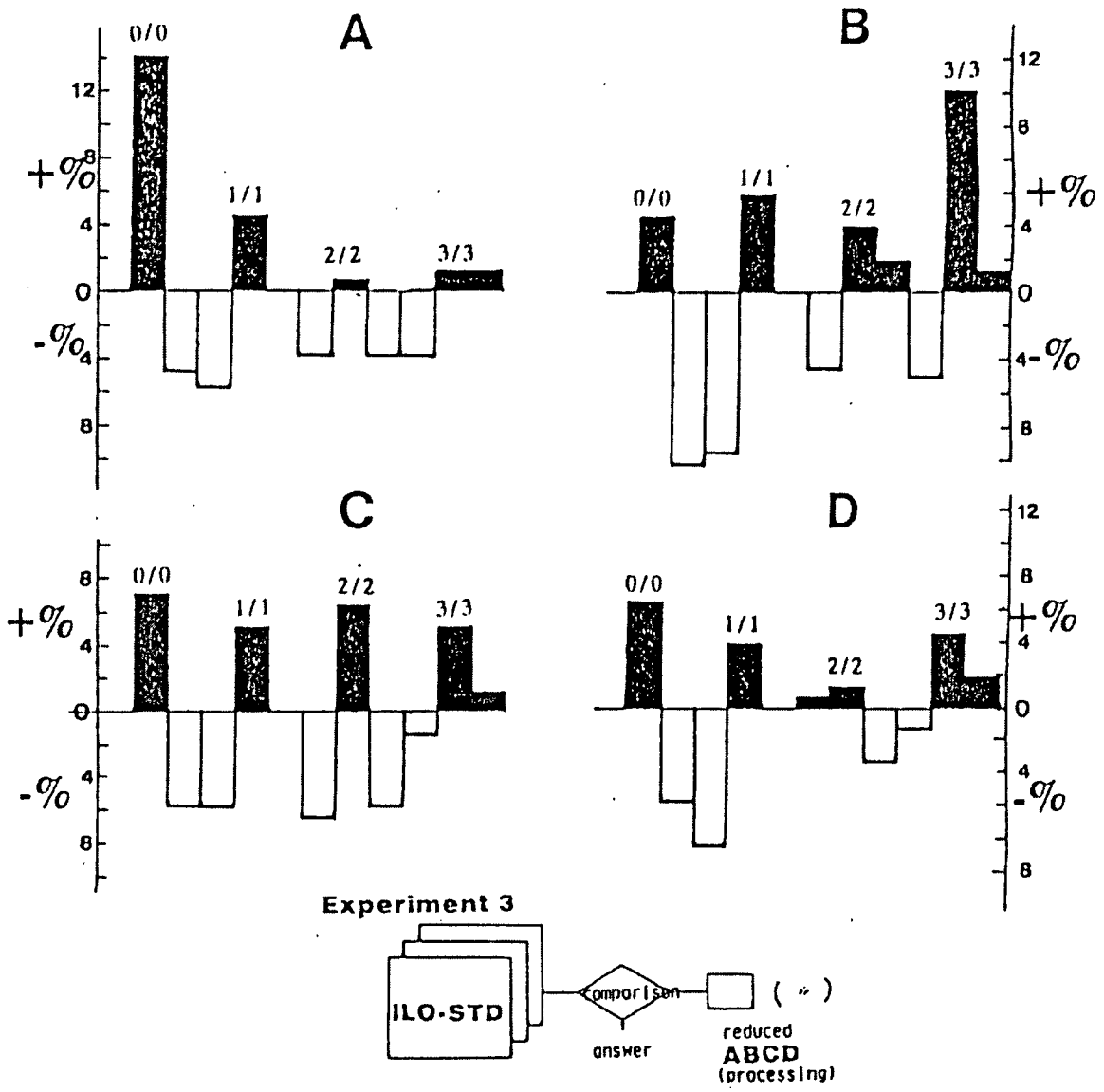
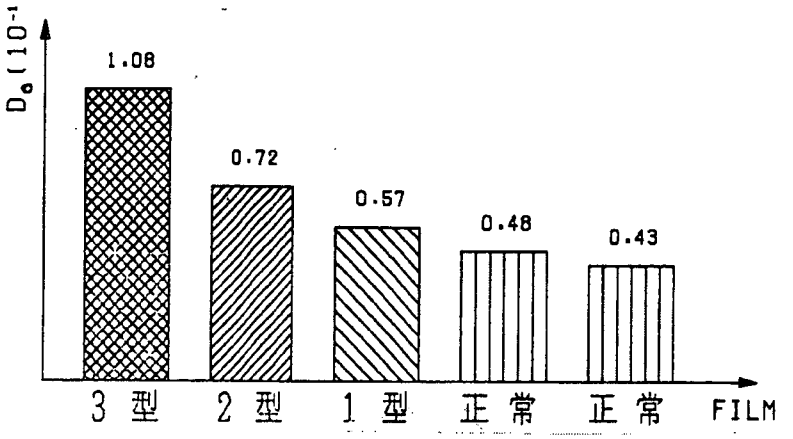
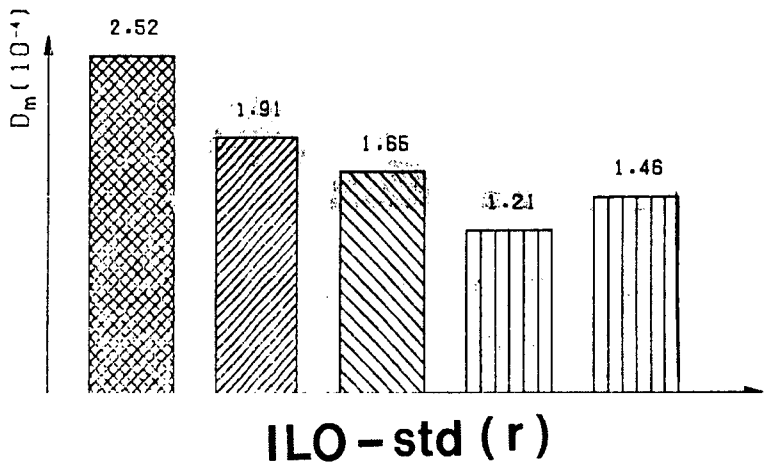

A
B
C
D
0/0
1/1
2/2
3/3
+%
-%
12
8
4
0
Experiment 3
ILO-STD
comparison
answer
reduced
ABCD
(processing)

図１１



小円形陰影領域成分の面積による密度（r型）



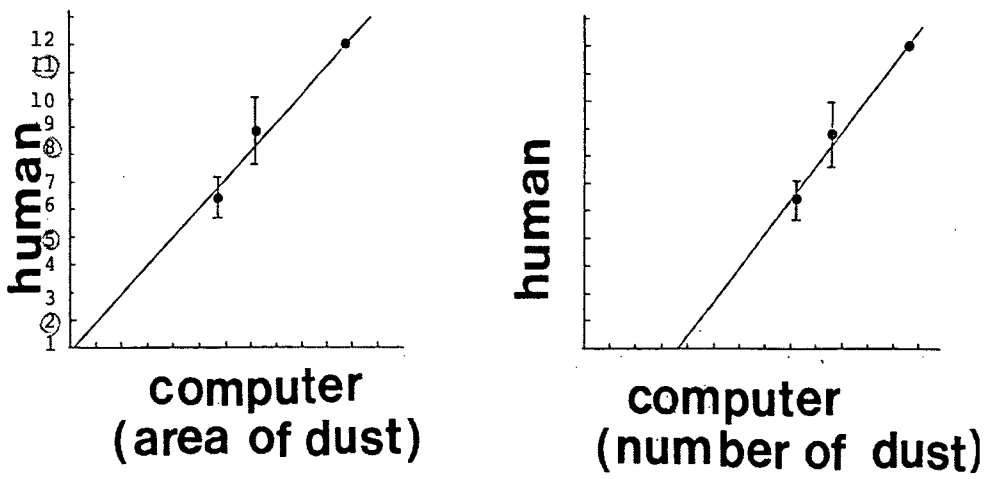


図 12　じん肺診断 CAD により計量されたダスト量（数、面積）と人による密度分類結果の対応

資料1

Effects of Image Quality and Film Size of CR Image on Pneumoconiosis Diagnosis

Yukinori Kusaka ,Toru Matsumoto, Toshio Shida and Yutaka Hosoda

1. Introduction

For over many years, International Labor Organization (ILO) has discussed the classification of pneumoconiosis x-ray photographs and has published successive guidelines on the topics. International standards for the evaluation of pneumoconiosis are presently based on guidelines published in 1980, and pneumoconiosis diagnosis is accordingly carried out by comparing an x-ray photograph of a subject with standard photographs prepared by ILO in 1980.

Recently, Fuji Computed Radiograph (FCR), a device which can collect, process and display x-ray photographs digitally, has been put to practical use widely in the diagnosis of pneumoconiosis.

The digitization of x-ray diagnosis of pneumoconiosis is considered to provide the following advantages.

1) Stable film density can be maintained in different photographs (the image quality is not influenced by photographic conditions.)
2) X-ray can be taken while exposing the subject to lower doses of radiation than present procedures.
3) The easily diagnosed x-ray photographs can be drawn by an image processor.

Pictures for pneumoconiosis diagnosis are usually full-scale size, but using FCR they are half the usual size and one quarter the area. (A note; but is different now in those days.) There are various ways to process an FCR image and an optimum image processing technique for pneumoconiosis diagnosis has not yet been determined. The present report addresses the following problems, which remain to be solved, regarding the practical use of FCR for pneumoconiosis diagnosis. (A note: A problem to be common to a current hard copy (CR, DR) and soft copy for digital images of pneumoconiosis)

1) Relationship between the accuracy of pneumoconiosis diagnosis and image quality.
2) Whether there are any effects due to the reduction of film size by half.

2. Materials and Methods

The order of experiments presented in this report are summarized in Fig. 1

Experiment 1: In this experiment, the normal comparison, ILO, full size, is compared to the full-size test. Full-size ILO films consisted of seventeen full-size standard films, as designated by the International pneumoconiosis x-ray classification. Full-size test films consisted of twenty-six pneumoconiosis films used for study in the USA and standard films prepared in W. Germany. As shown in Table 1, test films were classified by pneumoconiosis types according to the diagnosis of many medical specialists in each country (original diagnosis) carried out on actual, full-size films.

Table 1 presents the profusion, Shape and size of twenty-six pneumoconiosis films representing the final data for each film used in the present study.

Eight physicians participated in the comparison of 26 full-size test films with full-size ILO films, which are normally used for pneumoconiosis diagnosis. The pneumoconiosis diagnosis was carried out as follows:

1) The profusion of opacities was broadly classified into one of four types, 0, 1, 2 or 3 (twelve types in detail, 0/-, 0/0, 0/1, 1/1, 1/2, 2/1, 2/2, 2/3, 3/2, 3/3, 3/+).
2) Shape and size were classified into six types, p, q, r, s, t and u.
3) The lung field was divided into six areas, right, left; upper, middle and lower regions. The extent of the image was checked with the above classifications.

Experiment 2: This experiment examine ILO film reduction versus test film reduction. ILO reduction refers to film which underwent image processing C (described later) by a similar method to that used for FCR.

After full-size ILO films were digitized with a drum scanner, they were reduced in length by half, and by quarter in area. Test reduction refers to film which was reduced using the same procedure, but which underwent four types of image processing (Fig. 2), as follows (since there were 26 full-size test films, the total number of sheets came to 104):

processing A: γ=0.85
processing B: γ=0.85, rank 4, BE=0.50
processing C: γ=0.85, rank 2, BE=0.25
processing D γ=0.85, rank 4, BE=0.30

The same eight physicians carried out observations of reduced test films and compared them with reduced ILO films.

Experiment 3: This experiment compared ILO full-size films with reduced test films.

A total of 104 sheets of reduced test film were observed by six of the eight physicians who participated in experiments 1 and 2 and were compared with full-size ILO films. These experiments were performed in the order of 1, 2 and 3, and the eight evaluating physicians had no previous knowledge of FCR and had never observed reduced pneumoconiosis films prior to the present study.

3. Results and Discussion

3.1 Correspondence of final data to the pneumoconiosis profusion diagnosed by observation

As shown I Table 1, the 26 test films used as subjects in our observation included 10 out of a possible 12 scale, except 0/- (score1) and 3/+ (score12). Fig. 3 shows that the 26 films could be classified into to four categories, 0, 1, 2 and 3. The average scores of each pneumoconiosis profusion classified by the physicians was calculated and compared with a representative value of each category (0/0, 1/1, 2/2, 3/3). If the results of the observation experiment correspond to the final data, a straight, diagonal line should be obtained. The black circle represents the results of the comparison between ILO full-size and test-size films. The left graph of Fig. 3 shows the comparison of ILO full-size film versus reduced test film and ILO full-scale size film versus reduced test film and ILO full-scale size film versus test-size film. The right graph of Fig. 3 shows the comparison of ILO full-size film versus test full-size film and reduced ILO film versus reduced test film. In the case of test reduction by image processing A, standard and test films classified as type 0 were distributed above the diagonal line (higher profusion side), which is the usual case. However, films classified as type 1, 2, or 3 were distributed below the diagonal, or normal range, (lower profusion side). In the case of image processing B, all film types, with the expectation of type 3, were distributed on the higher profusion side. Processing types C and D tended to give distributions in the normal rang.

3.2 The average profusion classification and variance

The 12 diagnostic categories of pneumoconiosis classification were each given a score from 1 to 12 and the average score and variance were calculated for each case. The dotted line in Fig. 4 represents the relationship between the average profusion score (the horizontal axis) and the variance (the vertical axis) obtained in the experiment comparing ILO full-size versus test-full size (normal) films for film types 0, 1, 2 and 3, as evaluated by the eight physicians.

The average profusion classification for type 1 films was close to 1/0 (score 4), where the variance of scores is maximum. Thus, dispersion of pneumoconiosis profusion classification is maximal near the border between type 0 and type1. A similar tendency was seen in the

experimental results of ILO described in our previous report.

The pneumoconiosis classification guidelines published by the ILO in 1980 started that pneumoconiosis classification by x-ray films should be determined objectively from the fact without considering social insurance payment classification. However, these results suggest that doctors diagnose x-ray photographs without fully discriminating between type 0 and type 1.

Solid lines in the left graph of Fig. 4 represent the results of pneumoconiosis profusion classification obtained in the experiment comparing ILO full-size film versus reduced test film.

When classifying films reduced by image processing, using full-size ILO films as standards, diagnostic opinions among doctors were remarkably different, compared with the normal situation. The relationship between the average profusion classification and the variance differed according to the type of image processing. Especially in the case of processing B, type 0 was almost always classified as type 1 and the diagnoses differed greatly between physicians, unlike the normal pattern. The right graph of Fig. 4 shows the comparison between reduced ILO film, reduced test film and normal size film. There was less variance in the profusion classification compared to ILO full-size versus test reduction films. Examination of ILO reduction versus test reduction gave a near normal pattern. It was especially similar to normal films in the case of processing C.

3.3 Discrimination of profusion

The left half of Fig. 5 shows the discrimination of profusion for type 0 and type 1 and type 2 obtained in the comparison of ILO full-size versus test full-size films. The right half of Fig. 5 shows the results obtained from reduced test films (processing C) in comparison with reduced ILO versus reduced test films.

These curves were obtained by first determining the frequency distribution of the profusion (score) of the type 0 and type 1 films, as classified by the eight physicians. These distributions were then accumulation in the order of highest to lowest score. The percentage accumulation for scores of type 1 were plotted on the vertical axis and the percentage accumulation for score of type 0 were plotted on the horizontal axis. Curves in the upper left part of the graph indicate little overlap in the frequency distribution of scores obtained from type 0 and type 1. Thus, the higher distribution of profusion was demonstrated.

Fig. 5 imply the following:

1) Discrimination between type 0 and type 2 was easier than that between type 0 and type 1.
2) The discrimination of profusion was equivalent for comparisons of full size ILO film versu full-size test films and reduced ILO film versus reduced test film.

Fig. 6 shows the comparison of profusion discrimination among experiments 1, 2 and , using the procedure described above. Discrimination of ILO full-size films from test reduction is lower than that of reduced ILO films from reduced test. In the comparison of full-size ILO films versus reduced test films (processing type C or D), the results obtained were within the normal range.

Fig. 7 shows the comparison of profusion discrimination between type 0, p and type 1, p. In the comparison of ILO full-size films versus reduced test films, processing type A showed similar effect to the normal method, while other types (B, C, D) showed lower effect. In the comparison of reduced ILO versus reduced test films, discrimination of processing type A or C showed the same effect as the normal method. Fig. 8 shows the discrimination of shape q.

3.4 Ratio of correctly classified profusion

The films were classified into four types 0, 1, 2 and 3, and the ratios of correctly classified types (ratios of correctly classified profusions) were calculated from image reading. These results are presented in Fig. 9 and Fig. 10. The narrow line represents ILO full-size versus test full-size (normal comparison) films. The thich line shows the results of classifying the films reduced by the four processing methods in the experiments of ILO full-size films

versus reduced test and reduced ILO versus reduced test films. Fig. 9 suggests the following: in the comparison of reduced ILO versus reduced test films, the classification of profusion was higher than normal for type 0 and processing method A and was lower than normal for all other types. For processing method B, the rates for type 1 and type 3 were higher, and those for type 0 and type 2 were lower than normal. For processing methods C and D, the classifications were very close to normal but not completely normal. The results shown in Fig. 10 (ILO full-size versus reduced test films) display similar tendencies to those presented in Fig. 8. However, in Fig. 10 the drift from the normal range is greater than in Figure 9.

4. Conclusion

1) A half reduction of film length, or a reduction of area by a quarter, as in the FCR system, will not influence the diagnosis of pneumoconiosis using x-ray photographs, if appropriate image processing is carried.
2) The above experimental results suggest that the following image processing methods of FCR for film reduction are suitable: C (γ=0.85, rank=2, BE=0.25) or D(γ=0.85, rank=2, BE=0.30)
3) The results indicate the potential for the practical use of reduced films, because there was relatively little variance in observations, even through the evaluating physicians observed reduced films for the first time.

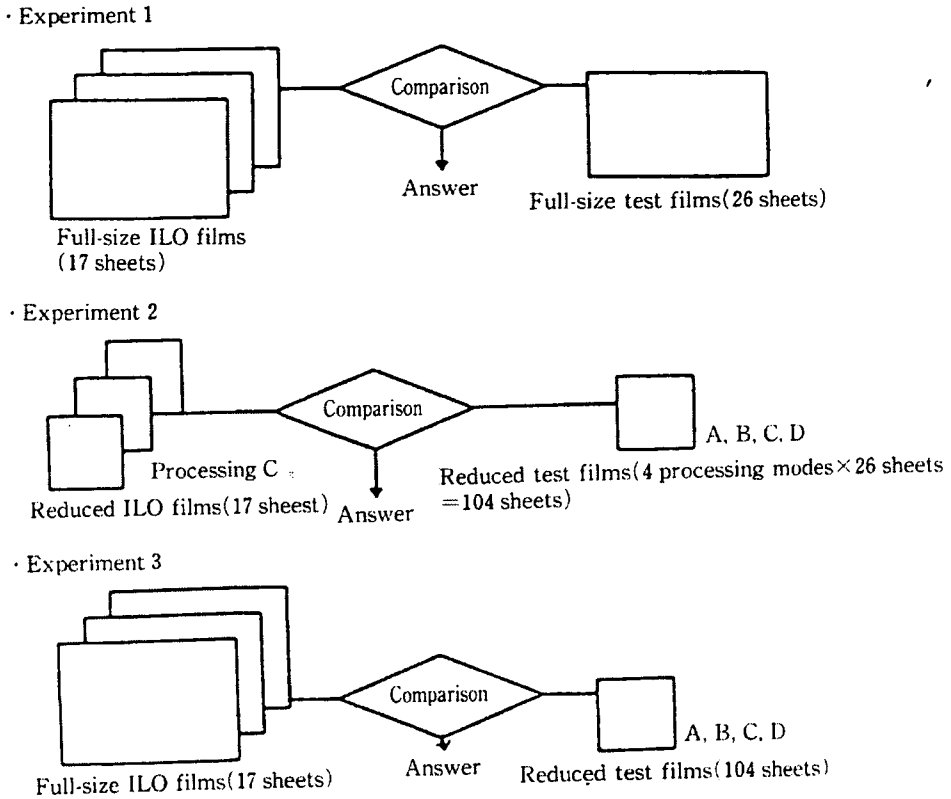
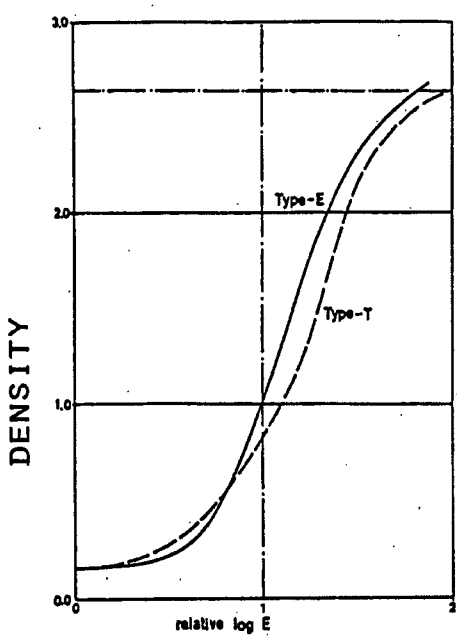
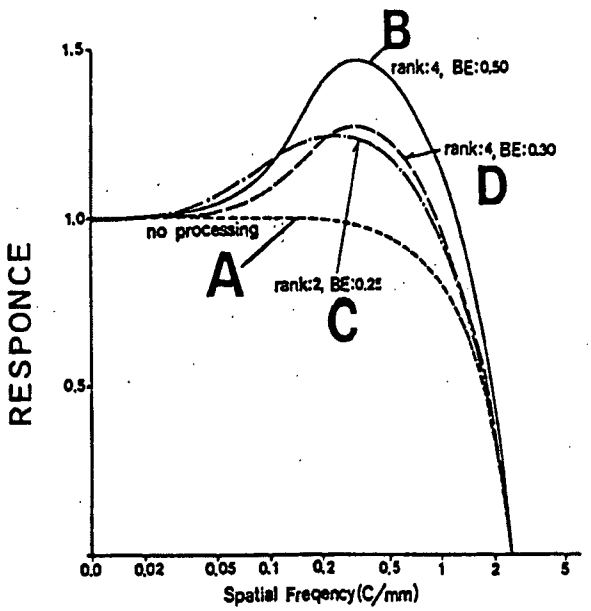


Fig. 1 Type and order of image reading study



Contrast characteristic curves of type E and T used for the processed film.



Spatial frequency characteristic curves used in final film reading of this study.

Fig.2 Image quality (A, B, C, D) of reduced test film of CR

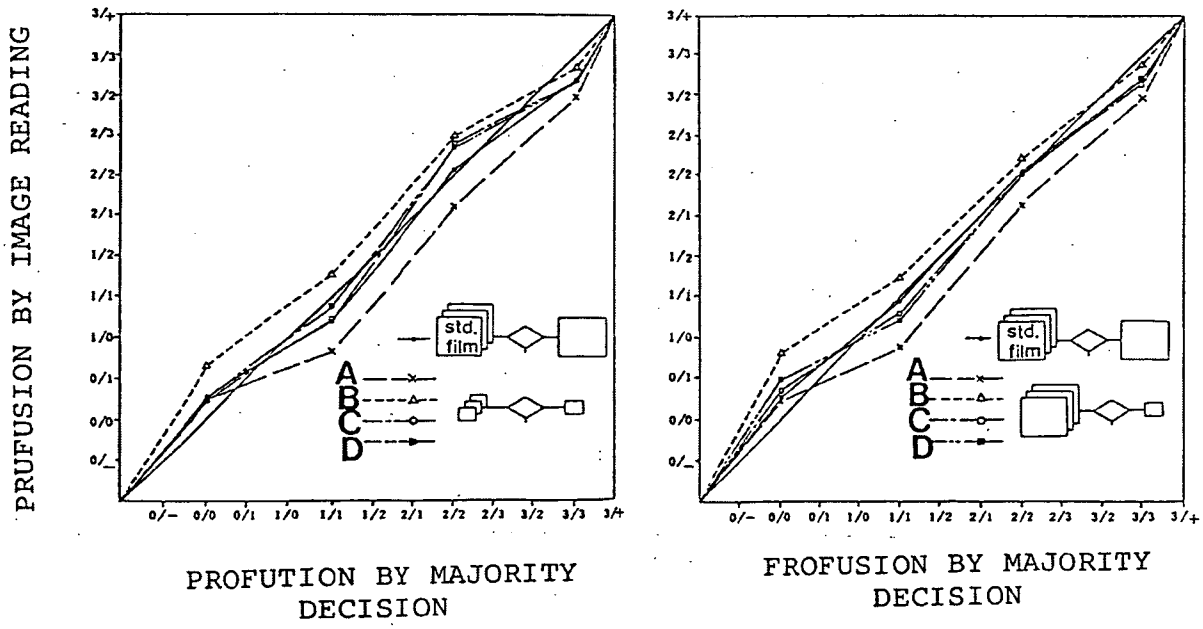


Fig.3 Relationship between results of profusion scoring by image reading study-1,2,3 and final diagnosis by three specialists

Table 1 Final diagnosis (profusion, shape/size) of full-size test films and reduced test films for the present study

		shape & size					
profusion	No. of case	p	q	r	s	t	u
0/0	3						
0/1	5	3			2		
1/0	5	3	1		1		
1/1	2	1					
1/2	1		1				
2/1	2		1				
2/2	3		3				
2/3	2		2				
3/2	2		1				
3/3	1		1				
total	26	7	10	1	4	1	0

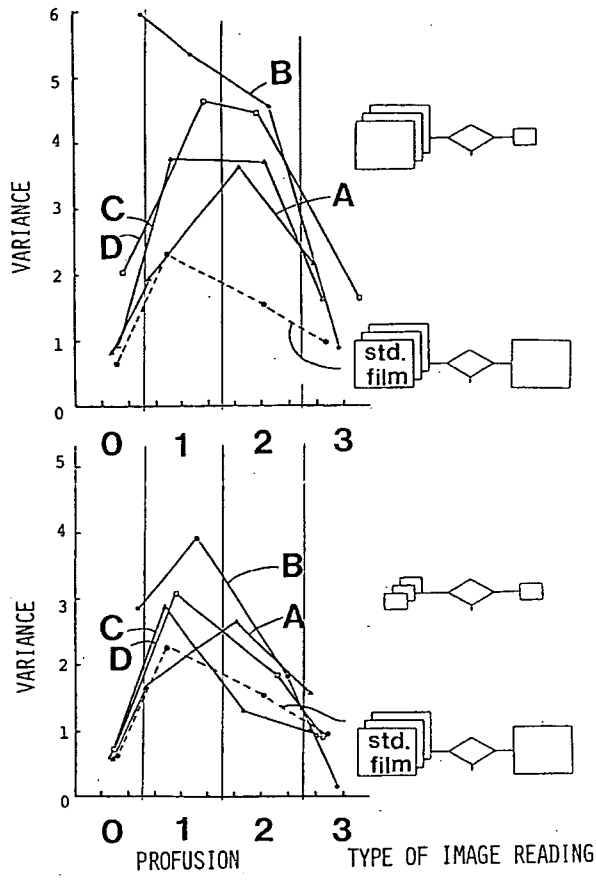


Fig.4 Relationship between average and variance of profusion score obtained by image reading study-1,2,3

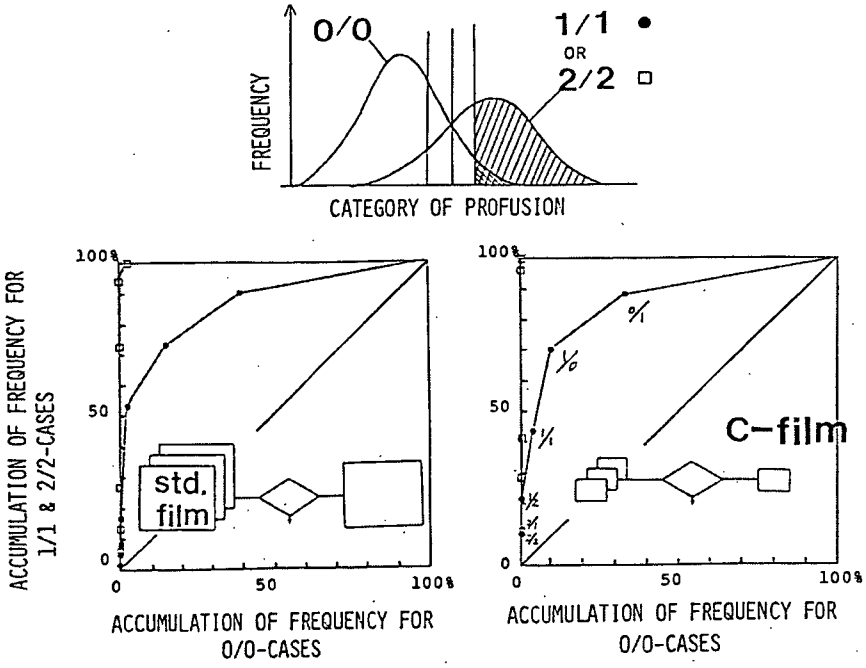


Fig.5 Discrimination of profusion (type 0 versus type 1-curve

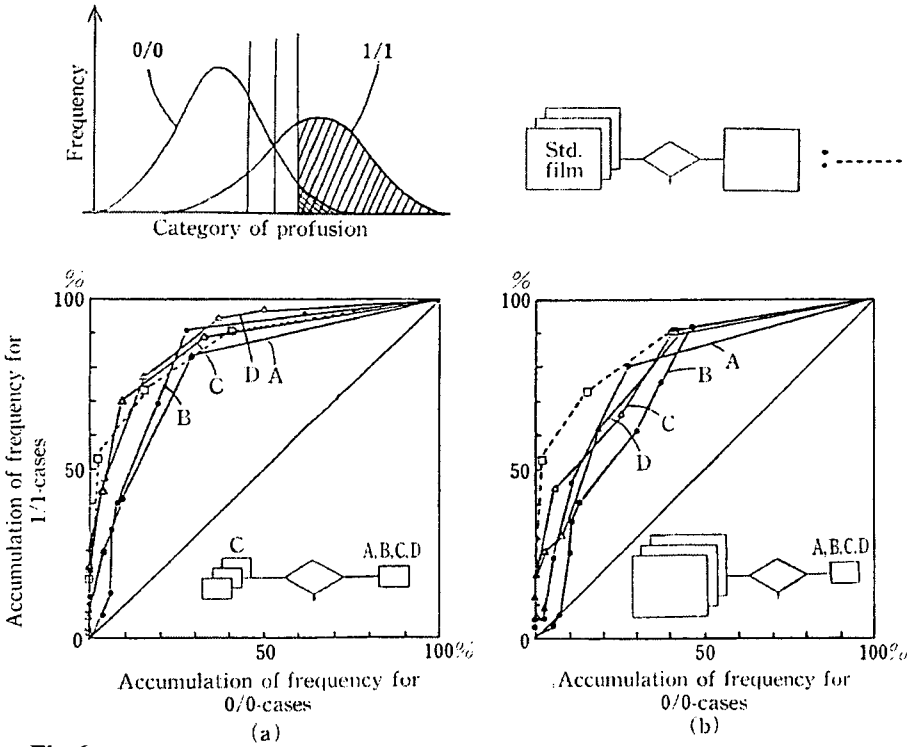


Fig.6 Discrimination performance of profusion categories of 0- vs. 1-type. Area under the ROC-curve in the case of the experiment-1=86%, (a) experiment-2 : A=80%, B=81%, C=86%, D=88%, and (b) experiment-3 : A=79%, B=75%, C=82%, D=78%

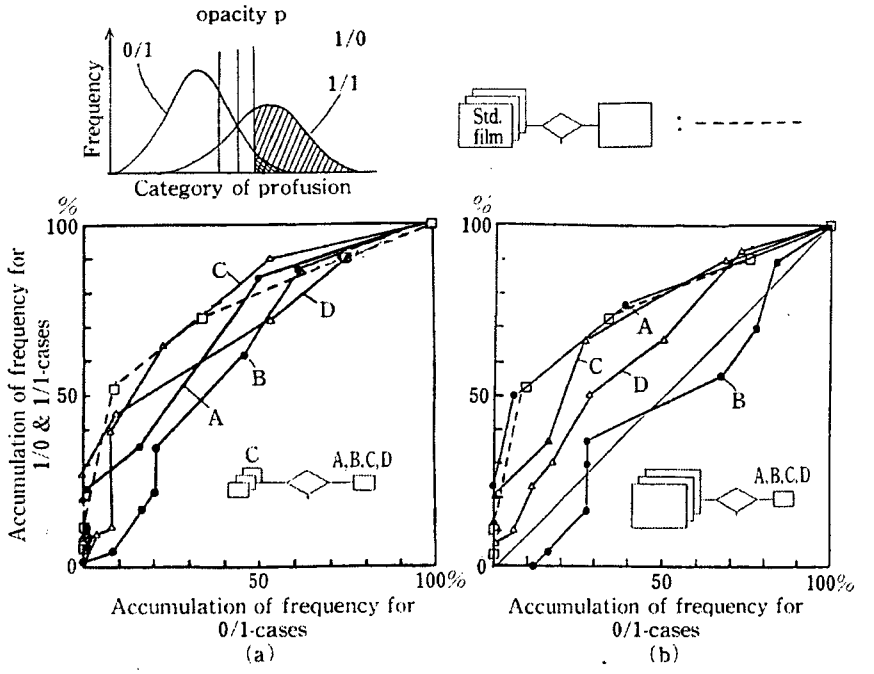


Fig.7 Discrimination performance of profusion categories of 0-vs. 1-type in the case of the opacity p. Area under the ROC-curve in the case of the experiment-1=76%. (a) experiment-2 : A=71%, B=62%, C=75%, D=70%, and (b) experiment-3 : A=77%, B=47%, C=73%, D=65%

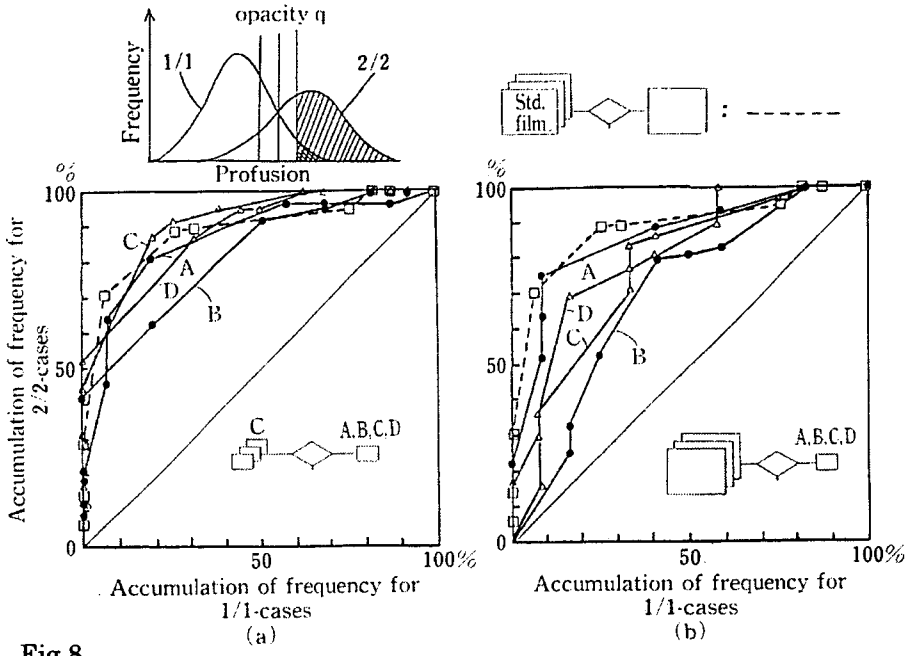


Fig.8 Discrimination performance of profusion categories of 1- vs. 2- type, in the case of the opacity q. Area under the ROC-curve in the case of the experiment-1 : 89%, (a) experiment-2 : A= 88%, B=82%, C=92%, D=89%, and (b) experiment-3 : A= 86%, B=71%, C=77%, D=81%

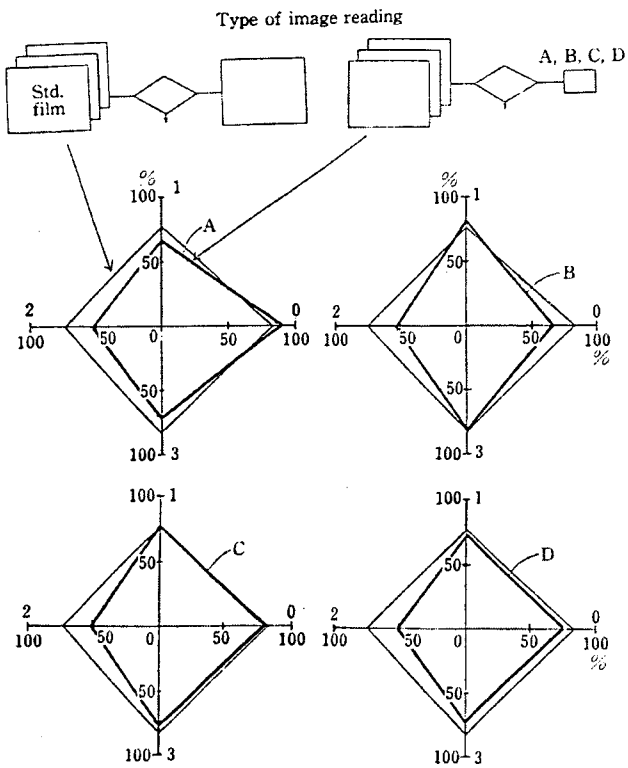


Fig.9 Ratios of correctly classified profusion. Comparison between ILO full-size versus test full-size films and ILO full-size versus reduced test films

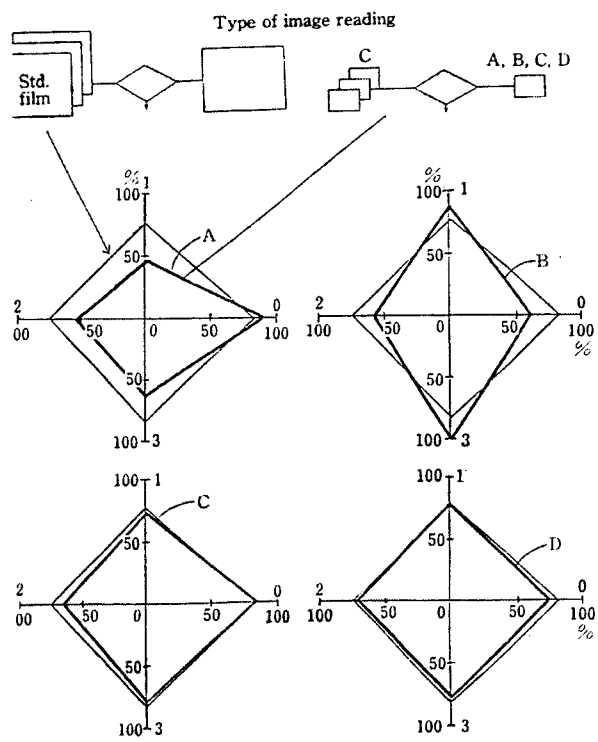


Fig.10 Ratios of correctly classified profusion. Comparison between ILO full-size versus test full-size films and reduced ILO versus reduced test films

資料2

Diagnostic Variations in ILO Standard Films (Rev. 80) for the Diagnosis of Pneumoconiosis

Yukinori Kusaka, Toru Matsumoto, Toshio Shida and Yutaka Hosoda et al.

1. Introduction

In the diagnosis of pneumoconiosis, the profusion, shape and size of dust in the lung are classified by reading X-ray films of the chest. Currently, international X-ray classification of pneumoconiosis which has been extensively used in various countries, is based on the text and standard X-ray films for the diagnosis published by ILO in 1980. These standard films were selected from image reading studies carried out by ILO for about 2 years from 1977 and presently play a role as a measure for the classification of the pneumoconiosis.

In this study, the data from that image reading study were reanalyzed to clarify inter-reader variations in interpretation of the standard X-ray films, to investigate factors affecting the accuracy and precision of the diagnoses of pneumoconiosis using X-ray films.

2. Material and methods

The image reading study data reanalyzed here, were obtained by ILO-working group for revision of the X-ray classification system of pneumoconiosis follows.

At first, prior to the image reading experiments, many X-ray films of patients with pneumoconiosis were collected from European countries, the USA and Japan, from which 106 films were selected as candidates for standard films. Next, one set of these films was sent to a representative of each country and were circulated among specialists of pneumoconiosis diagnosis for image reading. Image reading carried out with reference to the standard films prepared by ILO in 1971. Finally, the results of image reading were recorded in the image reading chart developed by ILO and were then sent to ILO.

As shown in "guideline for the use of ILO international classification of radiographs of pneumoconiosis " (Rev 80), various kinds of findings are detected by the interpretation of a X-ray film of pneumoconiosis. Fig. 1 shows a sample of the part of the image reading data on each film collected by ILO. Twenty seven physicians carried out image reading. The image reader number from 1 to 9 represent code numbers for Japanese readers, from 10 to 17 for American readers, and from 18 to 27 for European readers,

In this study, two kinds of data were reanalyzed, that is, (1) technical image quality subjectively estimated by physicians, (2) after differentiating small opacities into rounded opacities and irregular opacities, the profusion of opacities classified on a 12-point scale.

From these data, inter case variations, inter-reader variations and inter-nation variations in the diagnosis of pneumoconiosis were examined.

3. Results and Discussion

3.1 Means and standard deviations of profusion scores

The profusion of opacities on a X-ray film is classified on a 12-point scale. That is, physicians classify the profusion shown on a film into either 0/-, 0/0, 0/1 (0-type), 1/0, 1/1, 1/2 (1-type), 2/1, 2/2, 2/3 (2-type), 3/2, 3/3, or 3/+ (3-type). This classification is performed assuming a linear relationship between the results from X-ray classification and the dust weight in dissected lungs which had been demonstrated in the studies in the 1950s. Scores 1 to 12 were assigned to each grade on the 12-point scale and the mean and standard deviation of the scores of 27 readers of each film were calculated as follows: means = $\Sigma x/n$: average of profusion scores and standard deviations (SD). Where, x is mean profusion, Σx is summation over reader 1-27, and n is equal to the number of reader. (27).

An example of the mean value and standard deviation of profusion of opacities obtained in