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The Influence of Film Processing Temperature and Time on Mammographic film Characteristics

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Abstract

The influence for developing temperature and processing time within film processing conditions was investigated using four mammographic films, Konica New CM, Fuji UM-MA HC, Kodak Min-R M and Kodak EB/RA (for rapid system). And Fuji UR-2, a double-emulsion film, was used as a control. Those sensitometric strips exposed by a sensitometer were processed in the different combinations of developing temperatures ranging from 28 to 36℃, processing times from 45 to 210 sec.

Average gradient, relative speed and base plus fog obtained from the measured film characteristic curves were evaluated for the different developing temperatures and times. Fuji UR-2 was scarcely affected and mammographic films were greatly affected in the different combinations without an increase in base plus fog except EB/RA. In New CM, UM-MA HC and Min-R M, the average gradients and the relative speeds increased as the developing temperature was higher and the developing time was longer, but the increases were limit on the combination of 36℃ and 210 sec in New CM and UM-MA HC. In EB/RA, the average gradients were almost constant and the relative speeds increased slightly like the double-emulsion film. These results suggested that it would be possible to contribute to dose reduction and advancement of contrast in New CM, UM-MA HC and Min-R M by changing these processing parameters.

Key words : Mammography, Processing Parameter, Characteristic Curve, Average Gradient, Relative Speed

Introduction

In Europe and America, the influence of film processing parameters, especially the developing temperature and the developing time, has been studied to expect to improve film contrast and speed on mammography[1)-6)]. As an example, the extended-cycle process, in which processing time is longer than manufacture's recommendation, is a method used practically. This method makes effective use of the characteristics that single-emulsion films (mammographic films) are affected by processing conditions greater than double-emulsion film (conventional films).

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In Japan, as the incidence of breast cancer increased, the terms of about film processing parameters have been discussed as the important ones[7)-10)]. In the report of the 20th subcommittee of Japanese Society of Radiological Technology, the extended-cycle process was introduced and the terms of processing were described[8)]. Recently, general film processing cycle has gotten shorter and rapid screen-film systems for mammography have been developed, too. But there are a few reports about the influence of processing parameters for mammographic films and the reports in the West are only a few specific manufactures. From now on, the role of mammographic screening of breast cancer becomes important more and more. It is necessary to investigate changes of film characteristics in the differences of film processing conditions. So we studied how the characteristic curves on some kinds of mammographic films were affected by changing processing parameters with sensitometry.

Materials and Method

1. Materials

processor : Konica KX-170B

- developing temperature ranging from 28 to 36℃
- processing time ranging from 45 to 210 sec
- volume of developer tank 7 ℓ

sensitometer : Kodak process control sensitometer

densitometer : Konica PDA-15

single-emulsion film : Konica New CM, Fuji UM-MA HC, Kodak Min-R M, Kodak Ektascan B/RA(abbreviated EB/RA)

double-emulsion film : Fuji UR-2

developer/fixer : Konica XD-90C/XF-SR・C

2. Methods

We made film strips of the single-emulsion film with single sided exposure and the double-emulsion film with double sided exposure by a sensitometer. Those film strips were processed with each of processing parameter variations described in Table 1. The temperatures ranged from 28 to 36℃ with 2℃ increments and the processing times were 45, 60, 90, 150 and 210 sec. We set up twenty-five kinds of combinations of processing parameters and the five film strips were processed at the same time with each combination. Base plus fog and characteristic curves were obtained from measuring densities of the film strips with a densitometer. Furthermore, Average gradient, and relative speed were calculated from the characteristic curves. The film processor we used was modified to change the transport speed and we could select any processing times. The practi-

Table 1 Combination of processing parameters.

Chemical	Processing		(Film)
Developer / Fixer	Dev. Temp [℃]	Proc. Time [sec]	
Konica XD-90C / Konica XF-SR・C	28, 30, 32 34, 36	45, 60, 90 150, 210	Fuji UR-2 Konica New CM Fuji UM-MA HC Kodak Min-R M Kodak Ektascan B/RA

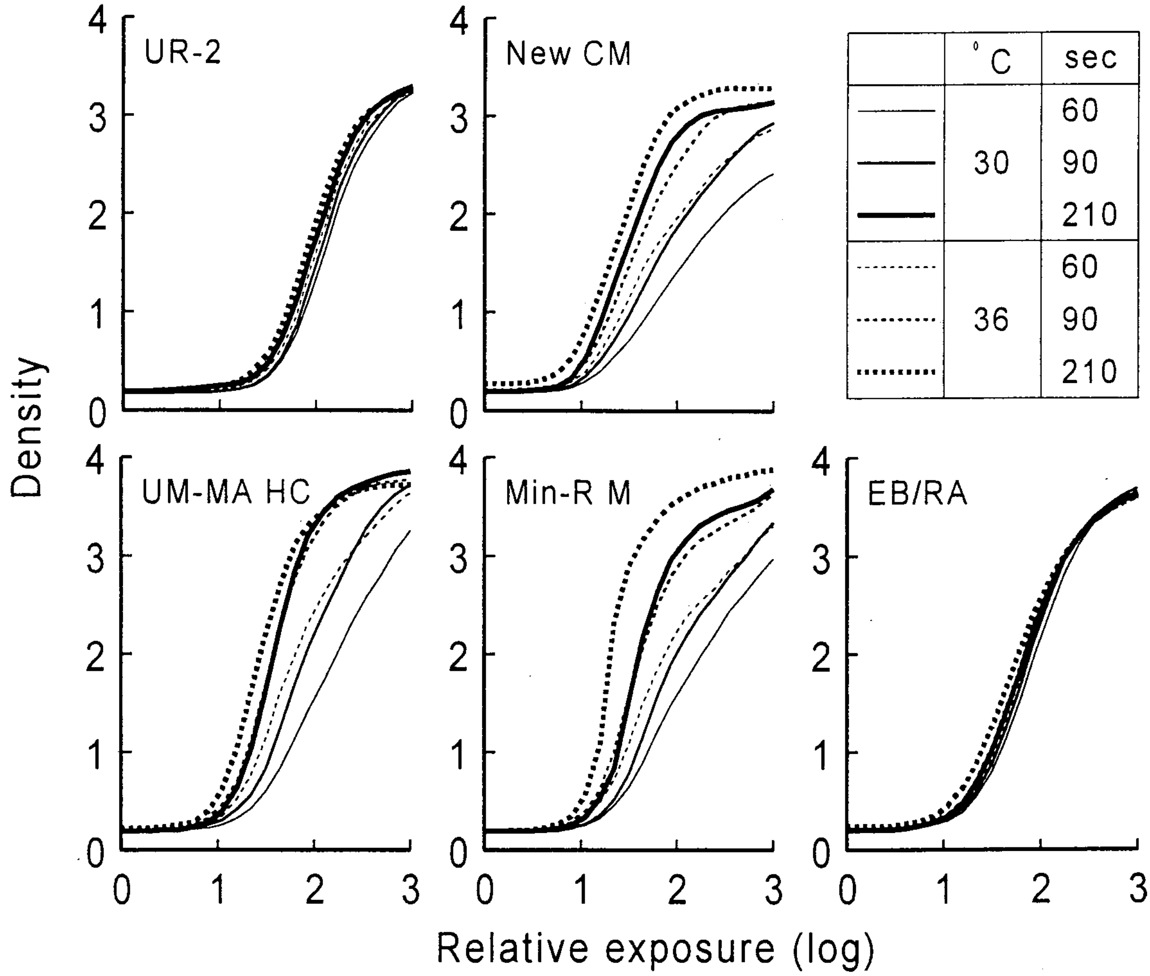

Fig. 1 Characteristic curves at developing temperature of 30℃ and processing time of 60, 90, 210 sec as well as 36℃ and 60, 90, 210 sec.

cal developing times in the processing times of our film processor were 11, 14, 21, 32 and 48 sec. They corresponded to processing times of 45, 60, 90, 150 and 210 sec.

Results

1. Characteristic curves

Characteristic curves at a developing temperature of 30℃ and processing times of 60, 90 and 210 sec and 36℃ and 60, 90 and 210 sec were shown in Fig.1.

The curves of UR-2 shifted slightly by varying the temperatures and times. The curves of EB/RA were similar to changes of UR-2. On the other hand, the curves of the others' mammographic films changed and showed that maximum optical density, contrast and speed increased as the temperature increased and the time was extended. The changes of each film were various and Min-R M showed the greatest increases.

Next, the base plus fog of each film was shown in Table 2. In most of films, the base plus fog didn't increase obviously, but at the

Table 2 Base plus fog for different processing times and temperatures.

UR-2

Dev. Temp. [℃]	Proc. Time [sec]				
	45	60	90	150	210
28	0.19	0.18	0.18	0.18	0.19
30	0.17	0.17	0.18	0.17	0.19
32	0.18	0.18	0.17	0.18	0.18
34	0.18	0.18	0.17	0.17	0.18
36	0.17	0.19	0.18	0.18	0.18

UM-MA HC

Dev. Temp. [℃]	Proc. Time [sec]				
	45	60	90	150	210
28	0.21	0.20	0.20	0.20	0.21
30	0.21	0.19	0.20	0.19	0.19
32	0.20	0.20	0.19	0.20	0.20
34	0.19	0.20	0.19	0.21	0.20
36	0.18	0.19	0.21	0.21	0.21

Min-RM

Dev. Temp. [℃]	Proc. Time [sec]				
	45	60	90	150	210
28	0.20	0.19	0.19	0.19	0.18
30	0.21	0.20	0.19	0.18	0.18
32	0.19	0.19	0.18	0.19	0.19
34	0.18	0.20	0.19	0.19	0.19
36	0.18	0.19	0.19	0.19	0.19

New CM

Dev. Temp. [℃]	Proc. Time [sec]				
	45	60	90	150	210
28	0.18	0.18	0.18	0.19	0.19
30	0.18	0.18	0.18	0.18	0.19
32	0.17	0.18	0.19	0.20	0.20
34	0.18	0.18	0.20	0.21	0.24
36	0.18	0.19	0.20	0.22	0.27

EB/RA

Dev. Temp. [℃]	Proc. Time [sec]				
	45	60	90	150	210
28	0.22	0.21	0.21	0.21	0.22
30	0.23	0.21	0.21	0.21	0.20
32	0.22	0.20	0.21	0.21	0.22
34	0.21	0.22	0.21	0.22	0.22
36	0.21	0.20	0.22	0.23	0.24

highest temperature and the longest time (i.e. combination of 36℃ and 210 sec) the increases in the base plus fog were on the order of 0.04 to 0.09.

2. Average gradient

The average gradients as an indication of the film contrast were shown in Fig. 2. The graphs were illustrated the average gradient on the vertical axis plotted versus the processing time on the horizontal axis at each developing temperature. The gradient of UR-2 changed slightly, on the other hand, the gradient of Min-R M increased obviously as the time was extended and the rate of the increase became larger as the time was extended. For example, when the temperature rose from 28 to 36℃, the increases in the gradient were 0.9, 1.2 and 1.8 at 90, 150 and 210 sec. In New CM and UM-MA HC, the influence by the temperature became the largest at 90 sec and exceeding the time resulted in the decrease in the gradient. Therefore, the gradient at the longest time of 210 sec didn't increase at the temperatures above 30℃. Furthermore, In the case of UM-MA HC at 150 sec, the gradient didn't increase even though the temperature rose from 34 to 36℃, too. Next, changes of the gradient of EB/RA were the least in the mammographic films. The gradient increased a little at 45 and 60 sec, but at exceeding 90 sec resulted in the changelessness or the slight decrease in the gradient.

3. Relative speed

Relative speeds compared with the combination of the developing temperature of 34℃ and the processing time of 90 sec in each film were shown in Fig. 3. As well as Fig. 2, Fig. 3 illustrated the relative speed plotted versus the processing time at each developing temperature. In UR-2 and EB/RA, the speed changed a little. In other mammographic films, the speed increased as the temperature increased and the

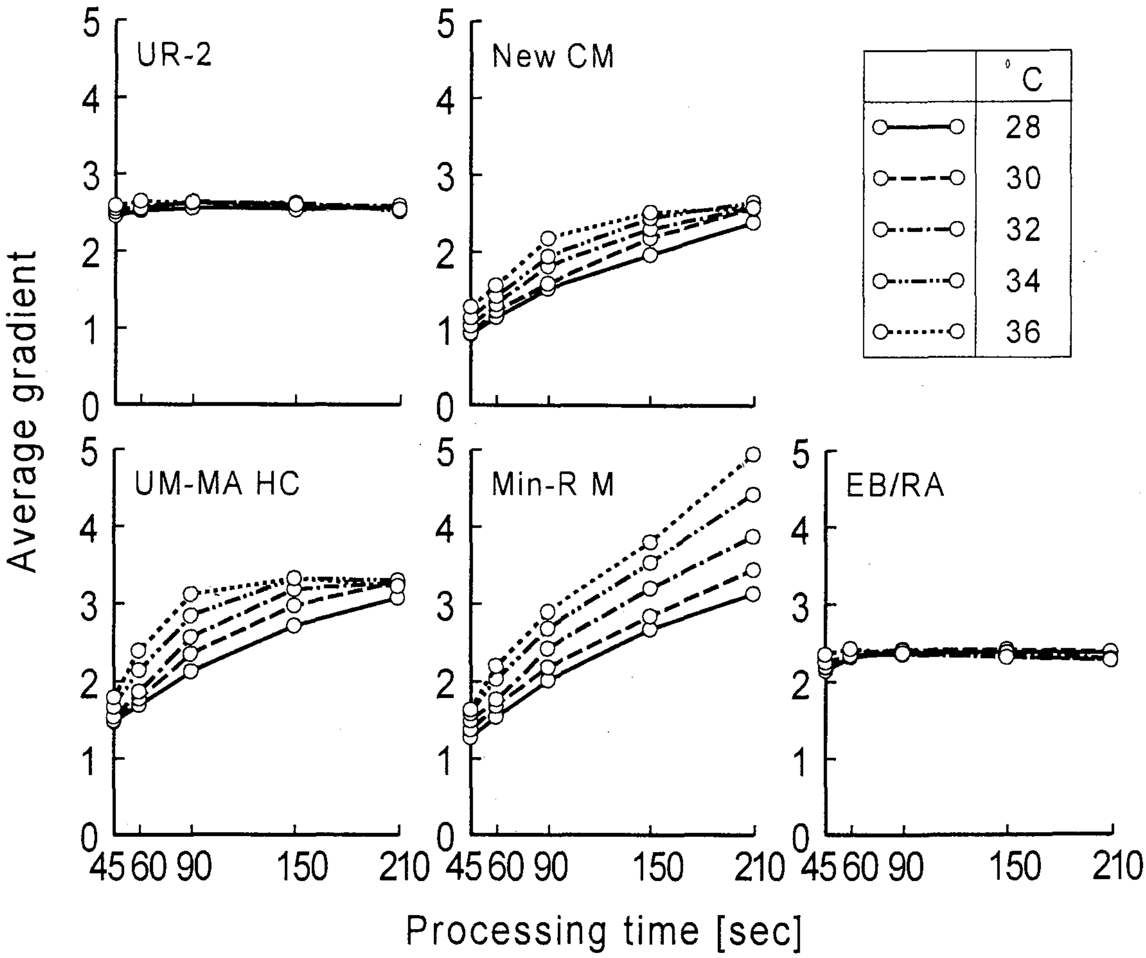

Fig. 2 Average gradient plotted versus processing time at each developing temperature.

time was extended. However, In the case of New CM at 210 sec, the speed at 36℃ was below that the value at 34℃. The maximum of the relative speed in Min-R M was about 200% and those of other mammographic films except EB/RA were about 160%.

Discussion

Recently, the double-emulsion films for a rapid system used tabular grains and are coated with less amounts of silver halide and gelatin than before[2,6]. The purpose seemed that the film could respond much less to change in the processing conditions, as the result of UR-2. On the other hand, single-emulsion films were coated with larger amount of silver halide and gelatin than double-emulsion film used in conventional radiography. Therefore mammographic films were influenced greatly for the developing temperature and time. In addition, used grains for the standard mammographic films (i.e. This "standard" means that the processing time was 90 sec of manufactures' recommendation.) were not tabular grains but three-dimensional grains or cubic grains. This is one of the cause to be affected easily for the developing conditions. However, EB/RA was scarcely affected in spite of single-emulsion

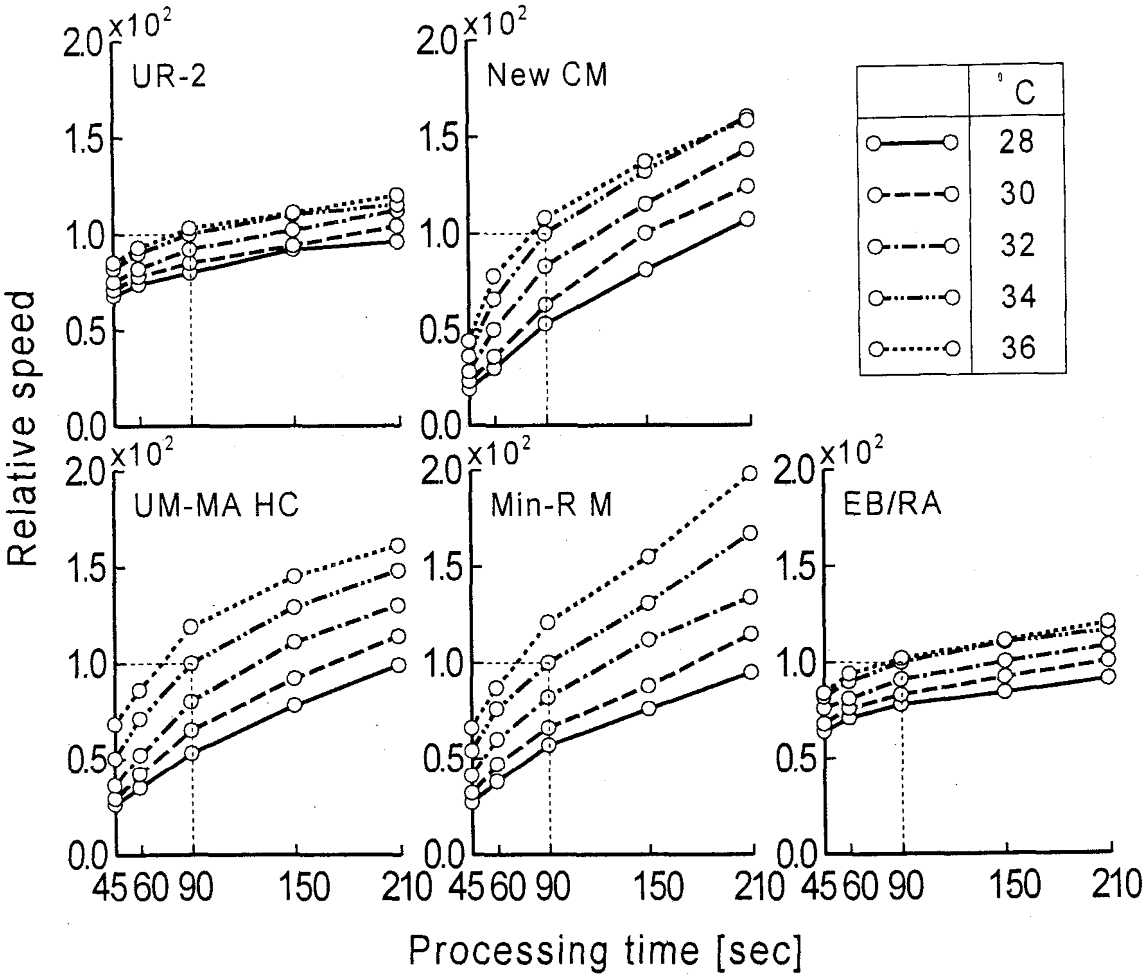

Fig. 3 Relative Speed plotted versus processing time at each developing temperature.

film. As referring to manufacture's guide, EB/RA used tabular grains as well as double-emulsion films for rapid system and it's processing time of manufacture's recommendation is below 45 sec.

Next, Fig. 4 illustrated the average gradient plotted versus the relative speed of each film in each combination of processing parameters. The point two dotted lines crossed in the graphs is the value in standard processing condition (34℃-90 sec). In Min-R M dramatic effects were seen and the average gradient and the relative speed could even increase with the higher temperature and the longer time than our setting them. In the cases of New CM and UM-MA HC at the longest time of 210 sec, the average gradient didn't increase even though we set above 30℃. About this, it could be considered that only the lower optical density increased against the higher optical density, since underexposure metallic silver was still in the process of the growth. The relative speed increased uniformly except New CM at 36℃ and 210 sec. As a result from Fig. 4, it was found that New CM, UM-MA HC, and Min-R M could be used for improving film contrast and

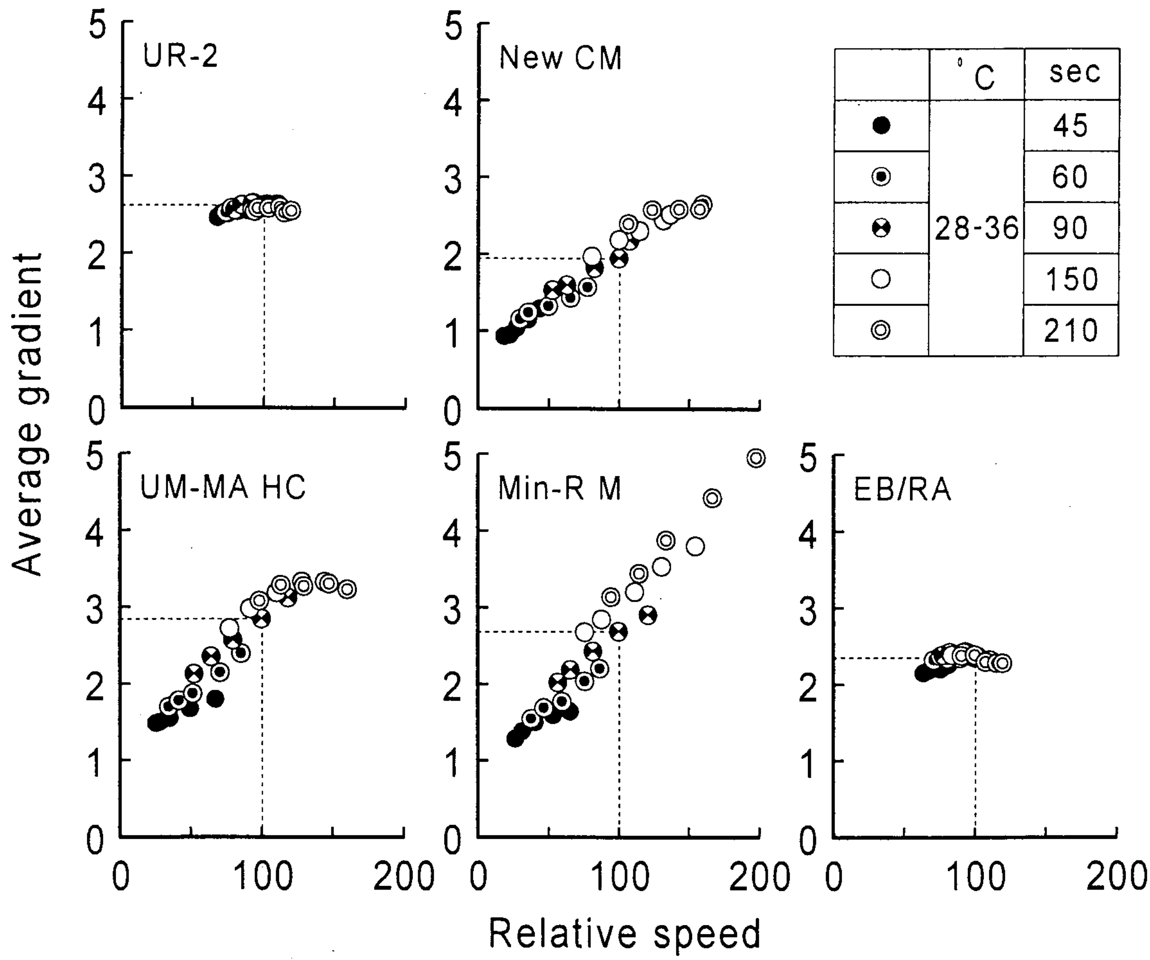

Fig. 4 Relationship between average gradient and relative speed at developing temperature from 28 to 36℃ and processing time from 45 to 210 sec.

speed by changing film processing parameters, and they should be researched more in other condition near to clinical trials like using a phantom. However, it is necessary for us to be aware of several important considerations as follow. Some film processors with the same processing cycle have the different developing time because of the different from the volume of the developing tank and the transport speed. Furthermore, a bad influence for granularity should be concerned because film's contacting time with the rollers in a processor is long when the long processing time is selected[9]. So the basic study about granularity should be investigated with useful processing parameters, too.

Conclusion

We summarized as follows from the results.

1. The base plus fog value didn't increase obviously in most of films by varying the processing parameters.

2. Changes in each film by varying the processing parameters.

・New CM : Both the average gradient and the relative speed increased but the increasing was limited at the highest temperature and the longest time.

・UM-MA HC: Though the tendency of changes was similar to New CM, in the average gradient the increasing was limit at the highest temperature and the longest time.

・Min-R M: Both the average gradient and the relative speed increased greatly.

・EB/RA: The tendency of changes was similar to UR-2 (the double-emulsion film). The average gradient varied scarcely and the relative speed increased a little.

3. New CM, UM-MA HC and Min-R M have the potential to improve the contrast and speed by varying the processing parameters.

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（原　著）

現像温度および時間のマンモフィルム特性に与える影響

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要　約

フィルム処理条件において，現像温度と処理時間に対する影響を4種類のマンモグラフィ用フィルムKonica New CM，Fuji UM-MA HC，Kodak Min-R M，迅速処理用Kodak EB/RAについて調べた。そして，比較基準用として両面乳剤フィルムFuji UR-2を用いた。感光計で露光したフィルムを現像温度28～36℃，処理時間45～210秒で処理した。

特性曲線から得られたフィルム特性（平均階調度，相対感度，カブリ濃度）を異なる現像温度，現像時間に対して評価した。UR-2はほとんど影響を受けず，マンモグラフィ用フィルムは，カブリ濃度が上昇することなく，現像条件の影響を大きく受けた。New CM，UM-MA HC，Min-R Mは現像温度の上昇，処理時間の延長に伴い，平均階調度と相対感度は増加した。しかし，New CM，UM-MA HCの36℃，210秒で増加は限度に達した。EB/RAの平均階調度は一定で，相対感度は両面乳剤フィルムと同様にわずかな増加であった。これらの結果は，New CM，UM-MA HC，Min-R Mにおいて，処理条件を変化させることにより，被曝低減，コントラスト向上に貢献できる可能性を示唆していた。

キーワード：マンモグラフィ，現像処理パラメータ，特性曲線，平均階調度，相対感度

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