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Abstract

To determine the characteristic curve of the radiographic screen/film systems in a short focal spot-film distance, the inverse square sensitometric method was modified by changing the radiation intensity with two kinds of filters. The characteristic curves obtained in the two exposure series with these two kinds of filters were overlapped to obtain a complete one. The characteristic curve thus obtained was almost the same as the one obtained by the original inverse square sensitometric method. The accuracy of the characteristic curves obtained by the modified method was well-reflected in the clinical radiographs.

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Modified Inverse Square Sensitometry for the Determination of the Characteristic Curve of Radiographic Screen/Film Systems

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To determine the characteristic curve of the radiographic screen/film systems in a short focal spot-film distance, the inverse square sensitometric method was modified by changing the radiation intensity with two kinds of filters. The characteristic curves obtained in the two exposure series with these two kinds of filters were overlapped to obtain a complete one. The characteristic curve thus obtained was almost the same as the one obtained by the original inverse square sensitometric method. The accuracy of the characteristic curves obtained by the modified method was well-reflected in the clinical radiographs.

Key words : sensitometry, characteristic curves, radiographic screen/film systems.

It is of fundamental importance for medical radiologists to select the screen/film system suited for each diagnostic purpose. Hence, the characteristic curve of each screen/film system must be accurately determined. To determine the characteristic curve of screen/film systems, several methods have been reported by various authors (1-6). Inverse square sensitometry is an intensity-scale sensitometric method considered to be of standard accuracy (7). For this method, several different types of sensitometers have been constructed (2, 8). In all of these, however, the distance from the focal spot to the film must be about 400 cm to obtain a complete characteristic curve. Such a long instrumentation is usually impossible in most institutions or hospitals. In the present study, an attempt was made to obtain a complete characteristic curve with a much shorter focal spot-film distance and use it in clinical applications.

Materials and Methods

Screen/film systems. Two screen/film systems were examined : the Toshiba EM/Fuji New RX screen/film system (EM/RX system) and the Fuji G-4/Fuji New RXO-L screen/film system (G-4/RXO-L system). The former has calcium tungstate screens with blue-sensitive film and the latter gadolinium oxysulfide screens with green-sensitive film.

Inverse square sensitometry. Inverse square sensitometry was done according to the method of Haus and Rossmann (2), using a single phase Toshiba KXO-15 (K) generator and a Toshiba DRX-191A x-ray tube (0.3/1.5 mm focus, 16° target). The output was monitored with an ionization chamber (Capintec 192X dosimeter

with 5.3 ml PM-05 probe). An exposure was made at each prescribed focal spot-film distance, producing 21 log relative exposure increments of 0.10. The distance ranged from 35 to 350 cm. The tube voltage was 70 kV. The x-ray beam was filtered through a basic filter consisting of 0.5 mm copper and 4 mm aluminum. The exposure time was 0.1 sec and the tube current 50 mA.

Modified inverse square sensitometry. A modification of the inverse square sensitometric method was used in which the focal spot-film distance ranged from 49 to 175 cm and the x-ray film exposure was performed in two series. In the first series, the exposure was made as follows : the tube voltage was 70 kV, the filter was the basic one, and the exposure was made at each prescribed focal spot-film distance from 49 to 175 cm to produce 12 log relative exposure increments of 0.10. In the second series, the tube voltage was 70 kV, the filter was the basic filter with a 1.1 mm copper filter added, and the exposure was made in the same way as in the first series. The copper filter was added to the basic filter to keep the highest optical density of the second series within the densities of the first one. The generator and the x-ray tube were the same as those used in the original inverse square sensitometric procedure. The exposure time and the tube current were 0.2 sec and 50 mA, respectively.

Film processing and densitometry. Exposed films were processed successively for 90 sec in a Sakura VX-400 automatic processor with Sakura XD-90C developer and XF-C fixer at 34℃. All films were read on a Sakura PDA-15 densitometer.

Average gradient of characteristic curve. The average gradient of the characteristic curve was calculated according to the formula of Eastman Kodak Co. (1).

Results

Drawing of the characteristic curve by modified inverse square sensitometry. Fig. 1 shows the x-ray film strips of the EM/RX system obtained in the first and second series of the modified inverse square sensitometric method. The optical density of each

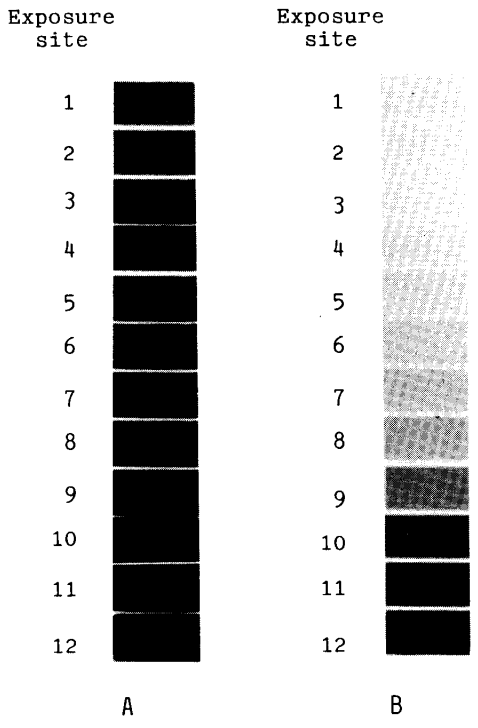

Fig. 1 Film strips exposed according to the modified inverse square sensitometric method (EM/RX screen/film system). A : First series of exposures in which the x-ray beam was filtered through the basic filter. B : Second series of exposures in which the x-ray beam was filtered through a 1.1 mm copper filter in addition to the basic filter.

film strip, and its corresponding relative exposure and log relative exposure are shown in Table 1. The characteristic curve which shows the relation between the optical density and the log relative exposure is shown in Fig. 2 : curve A was obtained in the first exposure series, and curve B in the second. The complete characteristic curve, curve C, was made by shifting curve A to overlap curve B.

Characteristic curves obtained by original and modified inverse square sensitometry. Four sets of measurements were done in each experimental series, and the data are summarized in Table 2. In the EM/RX system, the deviation of relative exposures in the modified inverse square sensitometric method from those in the original method

Table 1 Optical density and relative exposure in modified inverse square sensitometry[a,b]

Exposure series	Exposure site	Optical density	Relative exposure[c]	Log relative exposure
1st	1	0.73	1.000	0.000
	2	0.99	1.268	0.103
	3	1.29	1.581	0.199
	4	1.67	2.018	0.305
	5	2.00	2.541	0.405
	6	2.29	3.206	0.506
	7	2.49	3.936	0.595
	8	2.69	4.932	0.693
	9	2.86	6.252	0.796
	10	2.98	7.962	0.901
	11	3.05	10.02	1.001
	12	3.08	12.71	1.104
2nd	1	0.17	1.000	0.000
	2	0.18	1.262	0.101
	3	0.19	1.589	0.201
	4	0.20	2.014	0.304
	5	0.21	2.529	0.403
	6	0.25	3.170	0.501
	7	0.29	3.990	0.601
	8	0.38	5.023	0.701
	9	0.50	6.237	0.795
	10	0.67	7.798	0.892
	11	0.93	10.02	1.001
	12	1.26	12.65	1.102

a : Values were obtained with the film strips shown in Fig. 1.
b : Base plus fog density was 0.17.
c : Exposure at site 1 was normalized to 1.000.

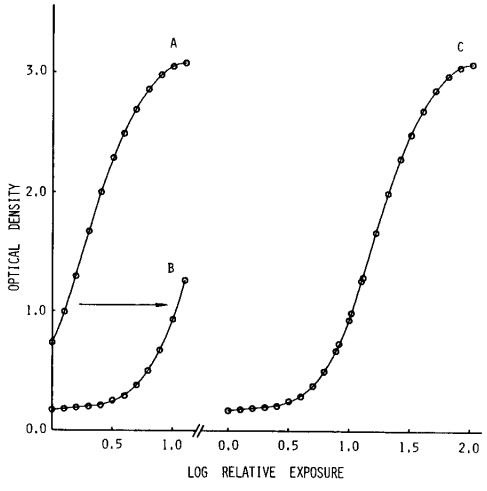

Fig. 2 Characteristic curve drawn by modified inverse square sensitometry (EM/RX screen/film system). A : The segment of the characteristic curve obtained in the 1st exposure series. B : The segment of the characteristic curve obtained in the 2nd exposure series. C : The entire characteristic curve obtained by shifting A to overlap B.

were within the range of ±3% in the useful optical density range of 0.42 to 2.17. The coefficients of variation of relative exposures in four sets of measurement were less than 2% in the range of useful optical densities in both the original and the modified methods. The characteristic curves drawn from the data obtained by these two methods were also almost the same (Fig. 3). The average gradients of the characteristic curves by these two methods were also nearly the same : 2.61 in the original inverse square sensitometric method and 2.71 in the modified one.

In the G-4/RXO-L system, as shown in Table 3 and Fig. 4, these two methods again gave almost the same results. The average gradients of the characteristic curves by the original and the modified methods were also nearly the same : 2.39 in the original and

Table 2 Optical density and relative exposure in EM/RX screen/film system[a]

Optical density	Relative exposure[b]	
	Inverse square sensitometry	Modified inverse square sensitometry
0.20	0.185±0.007	0.194±0.009 (104.9)[c]
0.30	0.378±0.006	0.393±0.009 (104.0)
0.40	0.492±0.004	0.509±0.005 (103.5)
0.60	0.672±0.002	0.685±0.002 (101.9)
0.80	0.836±0.001	0.843±0.001 (100.8)
1.00	1.000	1.000 (100.0)
1.20	1.173±0.002	1.165±0.002 (99.3)
1.40	1.360±0.006	1.344±0.004 (98.8)
1.60	1.570±0.011	1.543±0.008 (98.3)
1.80	1.810±0.019	1.773±0.012 (98.0)
2.00	2.095±0.029	2.045±0.018 (97.6)
2.20	2.444±0.042	2.384±0.025 (97.5)
2.40	2.899±0.060	2.831±0.033 (97.7)
2.60	3.542±0.084	3.482±0.043 (98.3)
2.80	4.603±0.122	4.602±0.068 (100.0)
3.00	6.989±0.338	7.055±0.289 (100.9)

a : Base plus fog densities in four measurements of the two methods were about 0.17.
b : All measurements were normalized to 1.000 at an optical density of 1.00, and each value represents the mean ± standard deviation of four measurements.
c : % ratio to inverse square sensitometry is given in parentheses.

Table 3 Optical density and relative exposure in G-4/RXO-L screen/film system[a]

Optical density	Relative exposure[b]	
	Inverse square sensitometry	Modified inverse square sensitometry
0.20	0.236±0.007	0.238±0.016 (100.8)[c]
0.30	0.389±0.004	0.404±0.019 (103.9)
0.40	0.491±0.002	0.509±0.015 (103.7)
0.60	0.665±0.001	0.678±0.009 (102.0)
0.80	0.829±0.000	0.837±0.004 (101.0)
1.00	1.000	1.000 (100.0)
1.20	1.185±0.001	1.177±0.002 (99.3)
1.40	1.393±0.003	1.376±0.003 (98.8)
1.60	1.635±0.005	1.610±0.002 (98.5)
1.80	1.929±0.009	1.895±0.008 (98.2)
2.00	2.306±0.014	2.265±0.021 (98.2)
2.20	2.833±0.022	2.791±0.048 (98.5)
2.40	3.707±0.037	3.681±0.109 (99.3)
2.50	4.490±0.053	4.487±0.173 (99.9)
2.60	6.019±0.133	5.997±0.300 (99.6)

a : Base plus fog densities in four measurements of the two methods were 0.16.
b : All measurements were normalized to 1.000 at an optical density of 1.00, and each value represents the mean ± standard deviation of four measurements.
c : % ratio to inverse square sensitometry is given in parentheses.

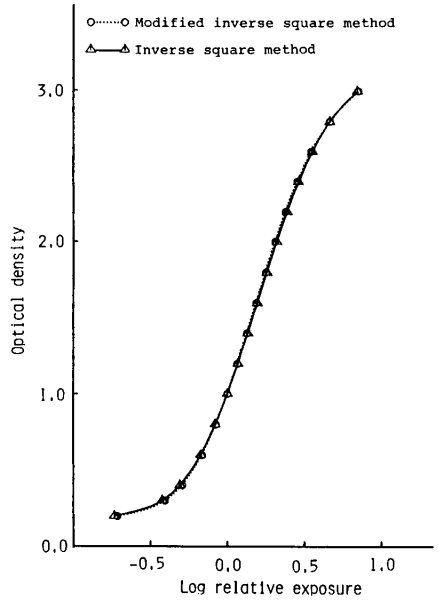

Fig. 3 Characteristic curves obtained by inverse square and modified inverse square sensitometric methods with the EM/RX screen/film system.

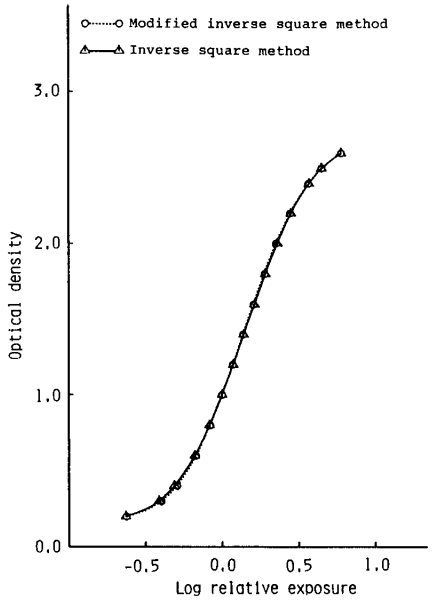

Fig. 4 Characteristic curves obtained by inverse square and modified inverse square sensitometric methods with the G-4/RXO-L screen/film system.

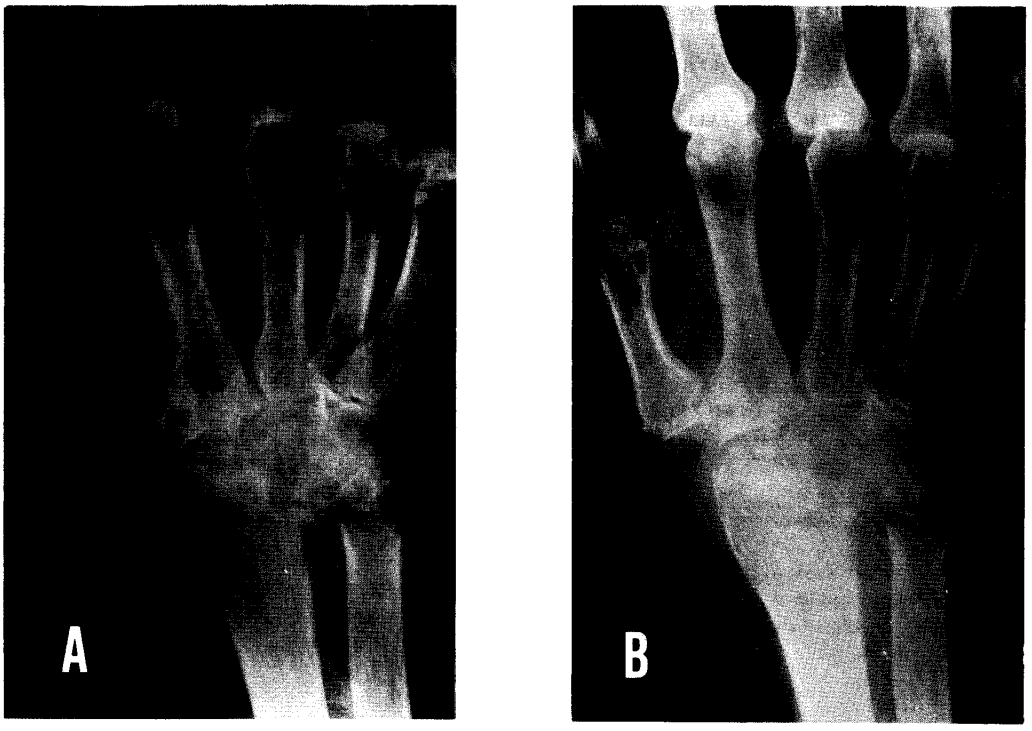

Fig. 5 Radiographs of a rheumatic hand taken with the EM/RX screen/film system (A) and the G-4/RXO-L screen/film system (B).

2.46 in the modified.

Clinical radiographs in EM/RX and G-4/RXO-L systems. As described above, the characteristic curves of the EM/RX and G-4/RXO-L systems obtained by modified inverse square sensitometry gave average gradients of 2.71 and 2.46, respectively, suggesting that the EM/RX system would give a higher contrast than the G-4/RXO-L system, whereas the latter would cover a wider range of radiation intensities. Radiographs of a hand were taken using these two systems. In Fig. 5A, which was taken with the EM/RX system, details of such hard tissues as bone trabeculae are more discernible than in Fig. 5B taken with the G-4/RXO-L system. In Fig. 5B, however, both bones and soft tissues are clearly observable, with the details of bone trabeculae being less discernible than in Fig. 5A.

Discussion

Inverse square sensitometry is considered to be of standard accuracy in the determination of the characteristic curves of radiographic screen/film systems (7). In this method, however, the focal spot-film distance must be about 400 cm. The modified inverse square sensitometric method reported herein required a focal spot-film distance of about 200 cm, and gave as accurate a characteristic curve as the original method. The properties of the characteristic curves determined by the modified method with the EM/RX and G-4/RXO-L systems were well-reflected in the clinical radiographs taken with these two systems. It thus appears that modified inverse square sensitometry would be of practical use in rather small institutions or hospitals.

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