Low-Dose Radiographic Equipment using Micro-Channel Plate Image Intensifier
(For Early Detection of Scoliosis)

Hitoshi Tanaka[+], Naonobu Sakai[+], Yoshinori Otsuka[++] and Yukio Tateno[±]
[+]The Institute for Training Radiological Technicians Affiliated to Chiba University School of Medicine
[++]Chiba University, School of Medicine, Orthopedics 1-8-1 Inohana Chiba-shi Chiba Japan, TEL 0472 (22) 7171
[±]National Institute of Radiological Sciences 4-9-1 Anagawa Chiba-shi Chiba Japan, TEL 0472 (51) 2111

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チャンネル二次電子増幅器を利用した低線量X線撮影装置
(脊柱側弯症診断に利用)

千葉大学医学部付属診療放射線技師学校
田中　仁　酒井尚信
千葉大学医学部整形外科教室
大塚嘉則
放射線医学総合研究所
館野之男

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我々は数年前より，X線撮影時における被ばく低減技術開発の一環として，チャンネルイメージ増幅器の利用について研究を続けてきた．今回，蛍光板↔チャンネルイメージ増幅器方式の低線量脊柱側弯症撮影装置を開発した．

本装置による被検者の被ばく線量は従来のX線撮影(HS：増感紙)に比し，約1/120と少ない．画質においては，解像力が7－8 *l*p/cmと従来のX線写真に比べ，かなり低下する．しかしながら，スクリーニングとしての脊柱側弯度を判定するには十分可能な画質であった．

1. Summary

Utilization of micro-channel plate image intensifier (MCP-I.I.) for one technique of low dose radiography has been researched for several years. Low dose radiographic equipment for detection of scoliosis based on a fluoroscopic screen and a channel image camera system have been newly developed. The X-ray dosage is only about 1/120 that of conventional X-ray radiography system (screen: HS). Resolution is low (7Lp/cm-8Lp/cm) compared with that of conventional radiography, but it is high enough to

measure the lateral curvatures for mass school screenings.

2. Introduction

According to the remarkable progress in recent medical care, it is generally recognized that, except some cases, the detectability of each disease in its early stage and its curerate are also increased significantly. Especially the diagnostic procedures utilizing X-rays have been advanced rapidly. While, from the point of view reducing the national significant dosage, the utmost effort about how to reduce the irradiation dosage in X-ray examinations is now widely requested from the society. X-ray diagnosis of scoliosis during children's school age is the important problem of the radiation hazard because the radiographic region contains the bone marrow and the gonades. Since recently the idiopathic scoliosis is largely incident to children during their school age, school screening of children for early detection has been executed[1]. But the most widely practiced visual inspection and palpitation have a disadvantage that the possibility of personal error in judgements by individual examiners could be so large, that there is a tendency to use X-ray diagnosis. Over forty times of X-ray examination are usually practiced for observation of convalescence during treatment. As stated above, large amounts of dosage are used for the diagnosis and the treatment of scoliosis, so the protection against radiation hazard is the objective. In order to lower the dosage of examinations, a low dose radiographic ezqipment based on the micro-channel plate image intensifier with high gain (transmission gain) and high resolution has been researched and produced since a few years ago and is now used for the examination.

3. Low-dose Radiographic Equipment

The newly developed low dose radiographic system which is manufactured in Japan consists of a fluoroscopic screen, and a channel image camera system based on the combined used of a Polaroid camera and Micro-Channel Plate Image Intensifier (MCP-I.I.)[2)–5)], arranged with lenses in front and back.

3—1. Imaging system[6)7)]

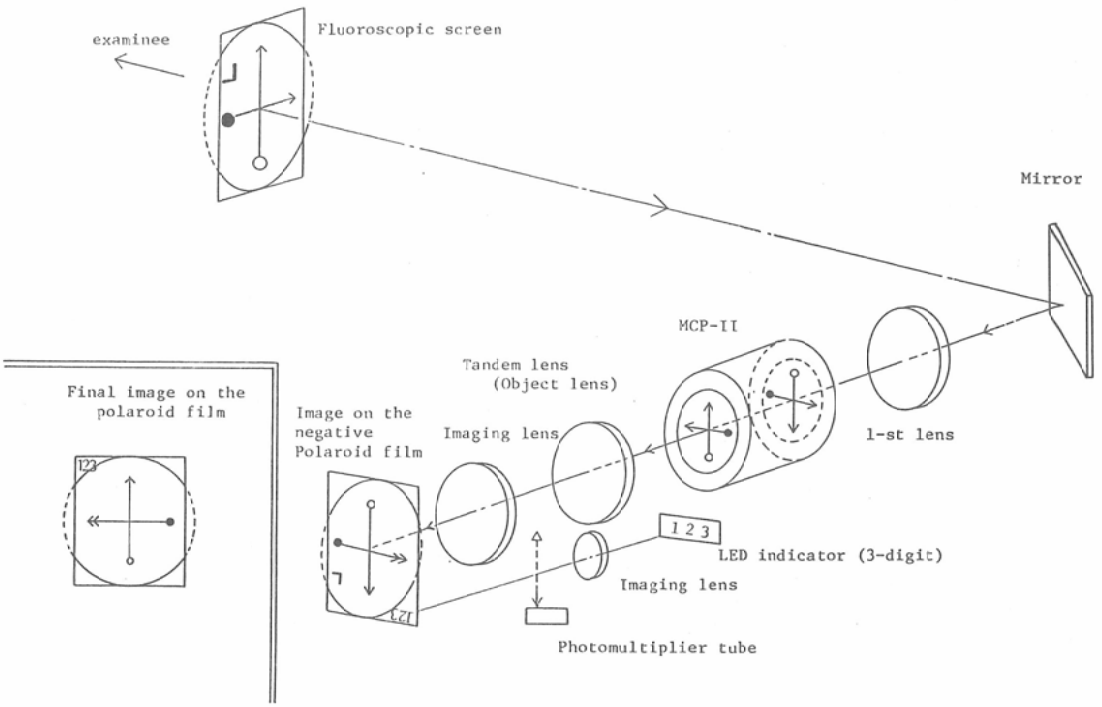


Fig. 1 Block diagram of imaging system.

Imaging system is shown in Fig. 1. X-ray image of the spine is converted to the optical image by a large fluoroscopic screen (Toshiba type-FU. 500×400mm). The size of the optical image is reduced to 20mm in diameter through the mirror and the first Hi-Fi lens (focal distance f=40mm). The reduced image is projected on the photocathode screen of the MCP-I.I. and is magnified by 3,000-25,000 times. The output image of MCP-I.I. is photographed with the Polaroid camera (Type 667 LAND FILM, ASA 3,000) through the secondary lens (tandem lens system : Object lens—Focal distance f=95mm, imaging lens— Focal distance f=3,000mm).

3—2. Micro-channel plate image intensifier (MCP-I.I.)

MCP-I.I. combined with the imaging system is manufactured by Mullard Limited, type 18 XX. In this MCP-I.I., the photo-electrons which is converted by the photo-cathode impinge on the microchannel plate and, after multiplication in the channels, are accelerated towards the phosphor screen. This accelerated photo-electrons are converted to the visible image on the output phosphor screen. Table 1 shows the characteristics of this MCP-I.I..

3—3. Accessories, etc.

Effective radiographic image that contains lumbar vertebrae and thoracic spine is required in the examination of scoliosis. In order to satisfy this requirement, compensation filter (Al) that keeps the uniform film density of the whole spine is attached in front of the X-ray tube, and the grid that eliminates the scattered X-rays is also mounted in front of the fluoroscopic screen. Positioning of examinee can voluntarily be adjusted by the automatic step table. Examinee identification number printer (3-digit) and the phototimer are also combined. Table 2 show these characteristics.

Table 1　Characteristics of MCP-I.I.

Input diameter	20mmφ Fiber
Photocathode	S—25
Output diameter	30mmφ Fiber
Phosphor screen	P—20
Input voltage	+2.6V DC
Dimensions	80×62mmφ
Mass	350gr
Resolution	45Lp/mm
Distortion	2%
Gain	3000~25000 times
	: 1m lux
	: 2cd/m²

Table 2　Low dose radiographic equipment

X-ray generator	Condenser type X-ray generator KCD-10B 100kV, 1μF, 10mA 0~5mAs
Grid	Grid ratio: 4:1 Grid density: 28 line/cm
Automatic step	Stroke (step height from the floor): 80~400mm Moving speed: 380mm/15sec
Polaroid camera	95×73mm

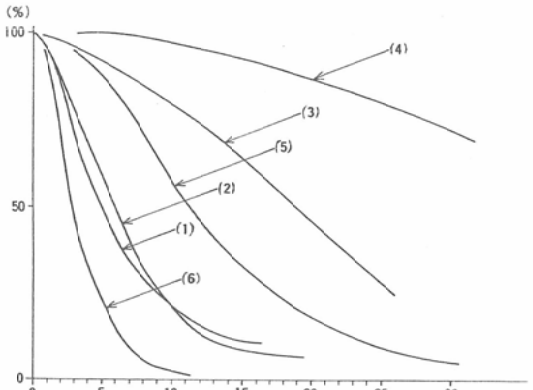


Fig. 2　Modulation transfer function converted to the input fluoroscopic screen. (1) Fluoroscopic screen, (2) MCP-I.I., (3) 1-st lense, (4) Tanden lens, (5) Polaroid film, (6) Total MTF, (1)×(2)×(3)×(4)×(5).

4. Image Quality

The lowering of image quality cannot be avoided because this equipment contains high gain MCP-I.I., Polaroid film, fluoroscopic-screen, lens system and so on. In order to get this image lowering rate, modulation transfer functions (MTF) of each component and that of total system are shown in Fig. 2. MTF of the MCP-I.I. itself is high enough (Fig. 2-(2)), but that of the total system combined with a fluoroscopic screen and lens system is lowered considerably (Fig. 2-(6)). Resolution of this total system is about 7-8Lp/cm and is high enough to detect the scoliotic deformity.

5. Dosage

In order to evaluate the dosage, surface dose of 16cm Mix-Dp that may be supposed the skin dose of junior-high students is measured. Dose meters are Victreen 555 (Radocon II), Probe 555-1DAS and Keithley model 35020. Distance between X-ray tube and measuring equipments is 133cm. The optimum film density is about 0.97 for the normal X-ray film density, and about 0.70 for the Polaroid film density respectively. This density is measured under the optimum X-ray conditions (X-ray tube voltage, current exposure time, Mix-Dp 16cm) for the detection of scoliosis. Table 3 shows the result.

6. Examinations

Fig. 3 shows the spinal images obtained by this system. From these photographs it is possible to detect the scoliosis and to roughly measure the angles of lateral curvatures. The image is not as good as that of normal X-ray radiography, so detailed examinations need normal X-ray radiography (Fig. 4). The second advantage of this system is the use of a Polaroid camera. Therefore, this system permits the mass detection of scoliosis since the radiographs can be observed immediately. First of all this system is used to the school screening program of scoliosis making the best use of these advantages. Now the initial screening methods of school screening for detection of scoliosis are visual examination or moiré photographing method, but each of these methods needs X-ray examination for the examinee with suspicion. Examinees with primary suspicion become 6-12% of all examinees not to overlook the scoliosis with over 20 degrees of lateral curvatures, but the examinees who really need the detailed examinations, are smaller than 1/3rd of them. From the view-point of protection against radiation hazard, low dose radiography the follows initial screening will be necessary to detect the real examinees who need the detailed examination. In 1979 and 1980, over 7,000 elementary-school children and junior-high students had secondary examination with this low dose radiographic equipment in the Metropolis of Tokyo and in Chiba prefecture. Usefulness of this equipment has been recognized.

The second use of this equipment is for outpatient clinic. Since this equipment may have an error in the measurement of the lateral curvature angle because of its low resolution and small size image, the most suitable usage is for the convalescent.

Table 3 Exposure dose

Input exposure doses on the phantom (16 cm thickness) under 70 kV.

Method	Dosage	Dosimetry
CIC-02A System	1.8 mR (Film density 0.70)	Polaroid film 667 Tube voltage 70 kV
Conventional X-ray Radiography System	210 mR (Film density 0.97)	Screen: HS Film: Sakura "A" type Grid: 5:1, 34 lp/cm Tube voltage 70 kV

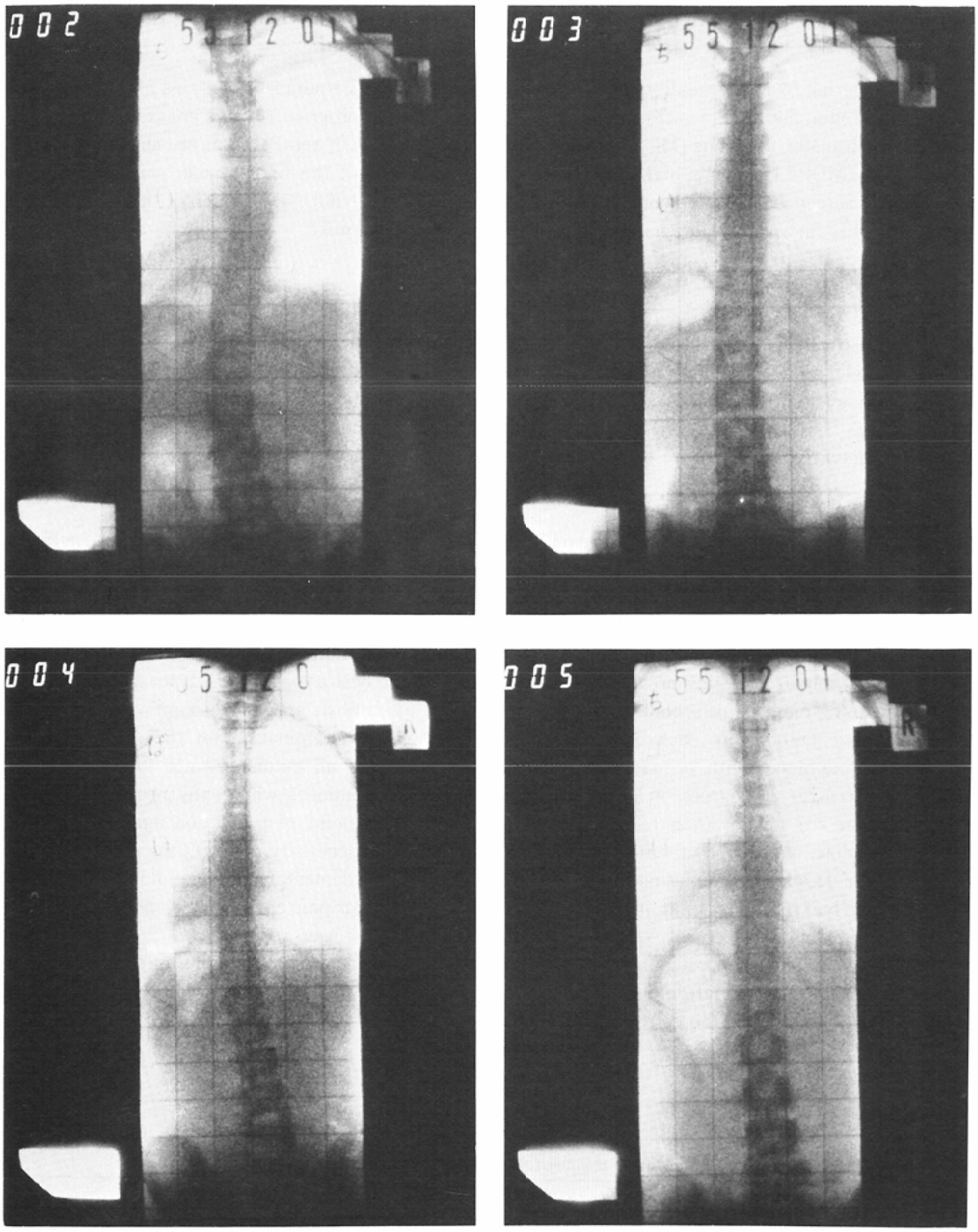
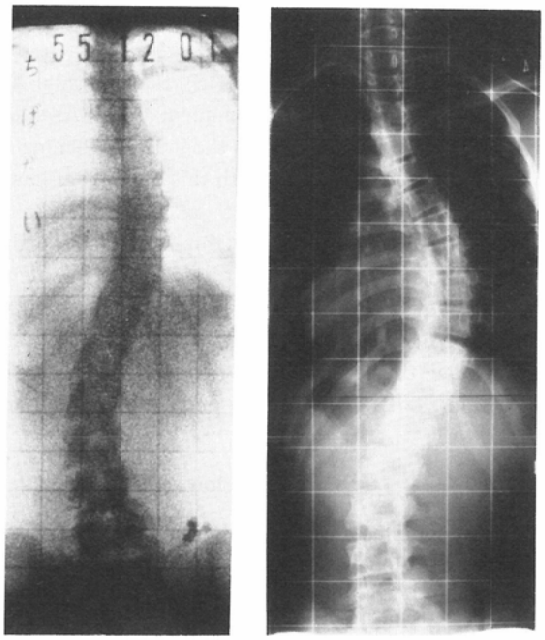


Fig. 3　Spinal X-ray photograph obtained through a low-dose X-ray photography equipment



(a) (b)

Fig. 4 Comparison of spinal X-ray photography between low dose X-ray photography system and usual X-ray system (same examinee). (a) Spinal X-ray photography by low dose system, (b) Spinal X-ray photography by usual X-ray system.

Every 4-6 months' use of this equipment is frequent enough for the observation of convalescent. Useful image can also be obtained when the patient has rectification equipment whose metal support does not overlap the spine on the X-ray film, and it is possible to reduce the number of normal X-ray radiography to 1/2nd or 1/3rd. Since the scoliosis is largely incident to children, and its observation and treatment are both practiced during their growing age, X-ray dosage should be extremely lowered. Hereafter when the image quality of equipment is improved, this will be widely used for daily examination in spite of a little increase of dosage.

7. Consideration

(1) Recently the patients of scoliosis have increased in number in Japan, and its early detection and early treatment is now being recognized as one of the major health problems for our society.

The patients who need the treatment have greatly increased, and especially 1.3-2.5% of elementary-school children and junior-high students need the treatment. During the treatment of scoliosis, observation is required every three months with spinal X-ray radiography, measurement of spinal curve pattern and that of spinal curvature angle. Most of the patients are infants, elementary-school children and junior-high students. Since the radiographic region contains the gonades, radiation hazard can be supposed serious.

(2) In order to lower the dosage of examinations, low dose X-ray photography equipment based on the MCP-I.I. has been developed. Spinal image with this equipment is not so good as that of the normal X-ray radiography, but it is good enough to roughly measure the spinal curvature angle and also in case of patient with Boston-style brace which is used for continuous treatment, it is possible to observe the

progress with this method every other time as we can see the effect of the brace while wearing it.

(3) The advantages of this equipment are as follows.

1) X-ray dosage is about 1/110th-1/120th (screen : HS)) that of usual X-ray radiography system.

2) Polaroid camera makes it possible to diagnose immediately. As stated above, this equipment is useful for the secondary screening method in addition to the initial screening method (visual examination and moiré photographing method). An X-ray truck with this equipment has already been produced and is now used for mass screenings of school children[1)8)].

(4) Image quality should be improved to widely apply this equipment to the examination fields. One improvable method is to use the microchannel plate that has a bigger diameter (over 75mm) than that of this one (30mm). But from the viewpoint of the whole imaging system, image quality can not be improved beyond the MTF of fluoroscopic screen (Fig.2, Curve 1).

When these problems are solved, this low dose imaging system will possibly be applied to low dose X-ray radiography, especially infants coxae radiography and pregnant woman pelvis examination, and to the X-ray television system.

8. Conclusion

(1) Low dose X-ray photography equipment for detection of scoliosis based on the MCP-I.I. with high gain and high resolution has been developed.

(2) The X-ray dosage is only about 1/120 of usual X-ray radiography system (screen : HS).

(3) Resolution is low (7Lp/cm-8Lp/cm) compared with that of usual X-ray radiography, but it is high enough to diagnose the scoliosis.

(4) A polaroid camera makes it possible to diagnose immediately, therefore low dose radiographic equipment with this camera permits the mass screening of scoliosis.

(5) Phototimer keeps the image reproducibility constant, and is useful for mass screenings.

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