Experience with RADspeed Pro style edition and Dynamic Chest Radiography

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1. Hospital Introduction

Kyushu University Hospital **(Fig. 1)** is located in Higashi-ku, Fukuoka City, Fukuoka Prefecture, and its branch hospital, Kyushu University Beppu Hospital, is located in Beppu City, Oita Prefecture. Kyushu University Hospital has 1,275 beds and is one of the largest national university hospitals in Japan with 752,416 outpatients (3,083.7 per day) and 413,987 inpatients (1,134.2 per day) in 2018. Kyushu University Hospital is also a “core hospital” responsible for advanced medical care in the western region of Japan and tasked with safely providing the latest and best medical care.

The Division of Radiology at Kyushu University Hospital operates with 5 physicians (2 with shared appointments), 67 radiological technologists, 10 nurses, and 10 clerical assistants. The division also works with more than 30 radiologists.

Fig.1 Exterior of Kyushu University Hospital (main site)

2. Equipment Characteristics

The RADspeed Pro style edition digital radiography system was first launched commercially in November 2018. When combined with Konica Minolta’s AeroDR fine digital radiography system, RADspeed Pro style edition is also capable of performing dynamic chest radiography. In March 2019, a RADspeed Pro style edition system was installed in 1 of our hospital’s 9 general (plain) radiography rooms (3 rooms for chest and abdominal radiography, 5 rooms for skeletal radiography, and 1 room for pediatric radiography). Because RADspeed Pro style edition is designed not just for dynamic chest radiography but also for use as a general radiography system, it provides good ease-of-use for applications other than dynamic chest radiography and a high level of versatility to perform various examinations. RADspeed Pro style edition also comes with a variety of functions and applications, some described below, and is designed to accommodate the wide-ranging needs of medical institutions **(Fig. 2)**.

(1) Auto-positioning function:
A single touch of the included remote control automatically maneuvers the ceiling-mounted X-ray tube support to a set position.

(2) Flat panel detector (FPD) auto-tracking function:
The longitudinal position of the FPD inside the Bucky table (supine radiography) is automatically linked to the position and angle of the X-ray tube unit.

(3) Vertical tracking function:
The focal height of the X-ray tube unit is linked to the Bucky stand and Bucky table height.

(4) Long view radiography function:
During radiography, the irradiation angle of the X-ray tube unit moves automatically to match the movement of the FPD when acquiring images. The acquired images are also automatically stitched together by the DR system.

(5) REALISM processing: A new image processing engine

(6) Intelligent Grid: An image processing technology for scatter correction

(7) Bone suppression: Thoracic bone attenuation processing

etc.

※ (5) to (7) are functions performed by the Konica Minolta DR system.

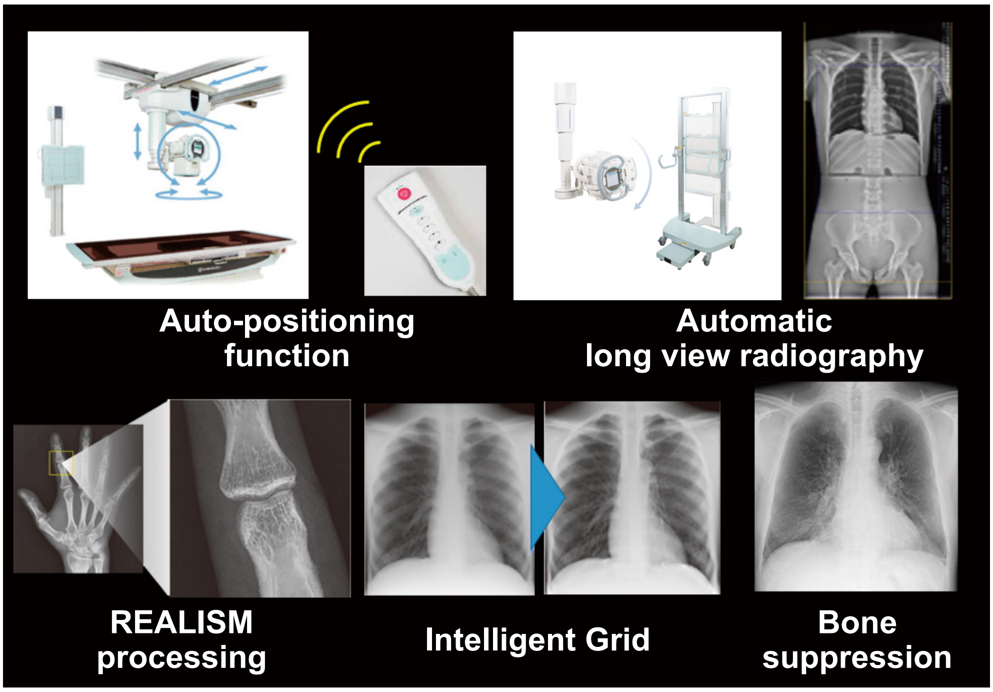

Fig.2 Various Functions and Applications for RADspeed Pro style edition

The FPD inside the Bucky stand and Bucky table can also be removed and used wirelessly to accommodate radiography of the head and extremities.

3. Image Transfer

The DR system can acquire two types of images: general radiographs (static images) and dynamic radiographic images (dynamic images). The image transfer workflow is shown in Fig. 3. After acquisition, static images are sent from the console to an image checking terminal, then transferred to the picture archiving and communication system (PACS). By contrast, dynamic images are transferred to a dynamic image analysis workstation to undergo sequential analysis processing, and the results of this processing are then transferred to the PACS. Static images and dynamic images can both be viewed from any terminal in the hospital.

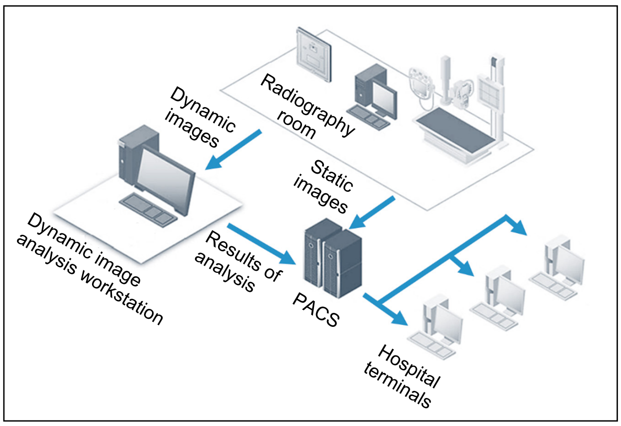

Fig.3 Image Transfer Workflow

4. Dynamic Radiography at Kyushu University Hospital

Kyushu University Hospital performs two types of dynamic radiography, a “deep breathing protocol” that acquires images during approx. 1.5 deep breaths and a “breath-holding protocol” that acquires images in a state of maximal inspiration where both protocols are performed upright or supine. The purpose of the deep breathing protocol is, through applying dynamic image analysis, to visualize signal changes associated with respiration, and the purpose of the breath-holding protocol is to visualize signal changes that occur in synchronization with the heartbeat. Each protocol is shown in detail in Fig. 4. The deep breathing protocol and breath-holding protocol require different guidance on breathing, hence different explanations and voiced instructions are provided to patients for each protocol.

5. Notes on Radiography

Images acquired by dynamic chest radiography are transferred to a dynamic image analysis workstation where, between each consecutively acquired image,

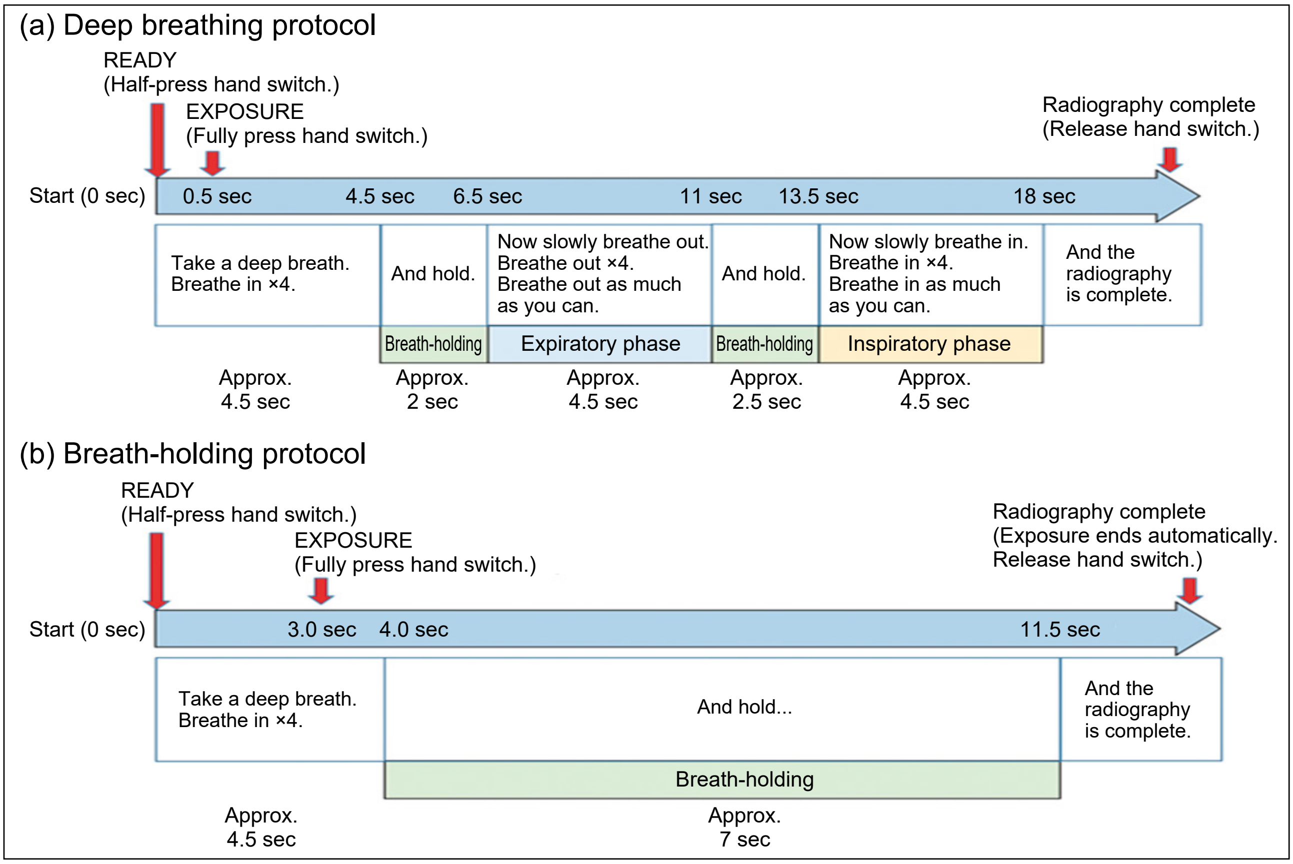

Fig.4 Two Dynamic Radiography Protocols Used by Kyushu University Hospital

pixel value changes arising from the physiological activity of tissue within the pulmonary field, such as alveoli and pulmonary arteries, are enhanced and undergo color-mapping analysis. During acquisition, patient movement other than respiratory movement or cardiac movement must be avoided because it can cause unwanted pixel value changes. Only pixel value changes caused by the movement of specific tissues within the pulmonary field are needed for dynamic analysis. For standing radiography of the chest performed in the posterior-anterior direction, image processing is prone to fail when an angle of 5 or more degrees is present between the patient and FPD laterally or anteroposteriorly. For this reason, the patient is immobilized as much as possible during acquisition to minimize body movement and maintain a correct body posture (Fig. 5). Specifically, the patient stands with feet at shoulder width and is attached to a Bucky stand by a belt around the pelvis. The patient also grasps front handles on the stand and positions their jaw slightly touching but not resting on a chin rest. During the deep breathing protocol, respiration may also cause patients to move their shoulders vertically, hence breathing exercises are performed beforehand so patients fully understand the type of imaging being performed and what precautions must be taken.

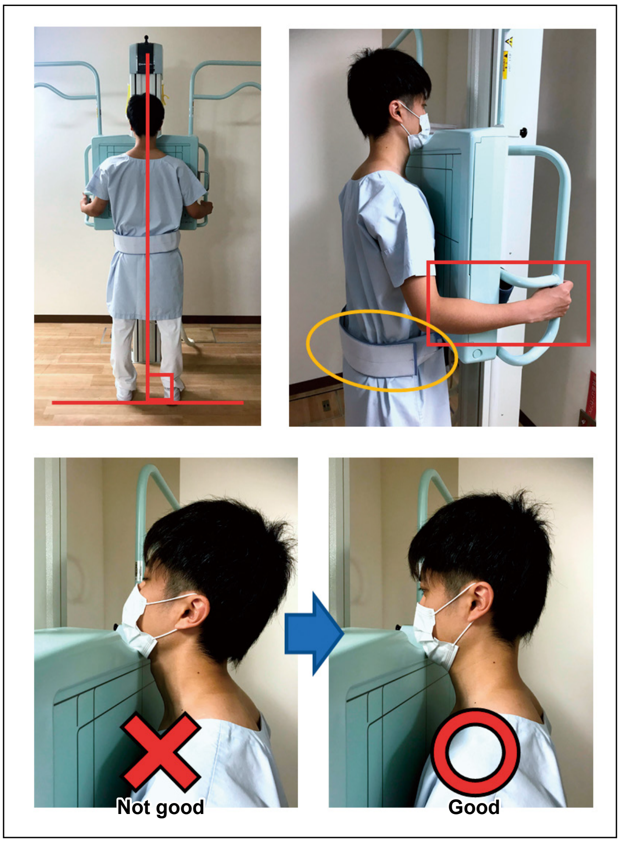

Fig.5 Positioning Measures for Standing Radiography

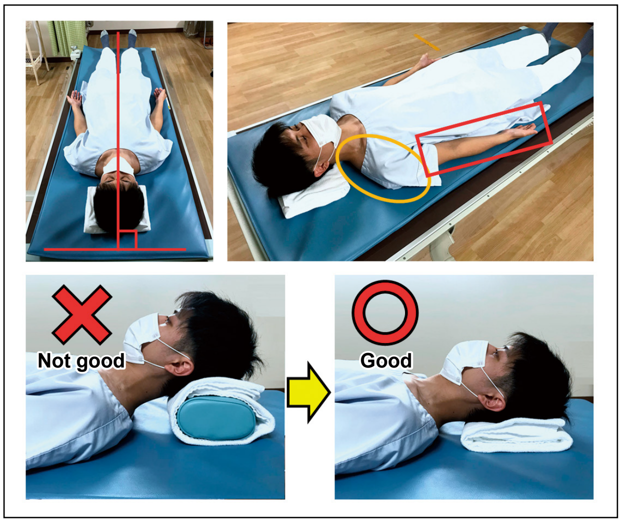

Fig.6 Positioning Measures for Supine Radiography

For supine radiography performed in the anterior-posterior direction, patients are placed in a fully relaxed position that includes the shoulders with elbows extended and palms facing upward. The pillow used for normal radiography raises the head, flexes the neck, and lowers the chin an excessive amount, hence a folded bath towel is used instead of a pillow (Fig. 6). Based on the range of motion of the equipment and the magnification of the subject, the source-to-image distance (SID) is set to 200 cm for standing radiography and 150 cm for supine radiography.

6. Exposure Conditions

No detailed investigations had been performed or reports published on optimizing exposure conditions for dynamic chest radiography. We investigated approaches to setting exposure conditions based on the body type of the patient. Basing this investigation on exposure conditions and patient body thickness and body type, patients were divided into three groups based on body mass index (BMI) and each examined with a different radiography tube voltage: (1) 85 kV for BMI < 17, (2) 100 kV for 17 ≤ BMI ≤ 25, and (3) 110 kV for 25 < BMI. Using the exposure conditions shown in (1), (2), and (3) above, the relationship between subject BMI and an image sensitivity indicator (S-value) measured clinically is shown in Fig. 7. When a value within 3,000 is taken as the target S-value for dynamic chest radiography images, at least 90 % of all images fell within this target. We now plan an extended study that focuses on S-values close to the target value and optimizes for these cases.

Based on the literature, the X-ray dose for dynamic chest radiography is approx. 1.5 mGy[1], which is lower than the guidance level for plain chest radiography (frontal chest view: 0.4 mGy, lateral chest view: 1.5 mGy, total: 1.9 mGy)[2] recommended by the International Atomic Energy Agency (IAEA). After the RADspeed Pro style edition was introduced to our hospital, entrance surface dose (ESD) measurements were taken to validate the exposure conditions used by our hospital. Exposure conditions were set to dynamic chest radiography conditionsused on a patient of standard body type (100 kV, 80 mA, 8 ms, Cu filter: 0.2 mm) with the breath-holding protocol. For comparison, ESD measurements were also taken in frontal view and lateral view with exposure conditions used for plain chest radiography. The results are shown in Fig. 8. The ESD for dynamic chest radiography was 1.24 mGy, higher than plain chest radiography but also lower than the IAEA guidance level (total of frontal

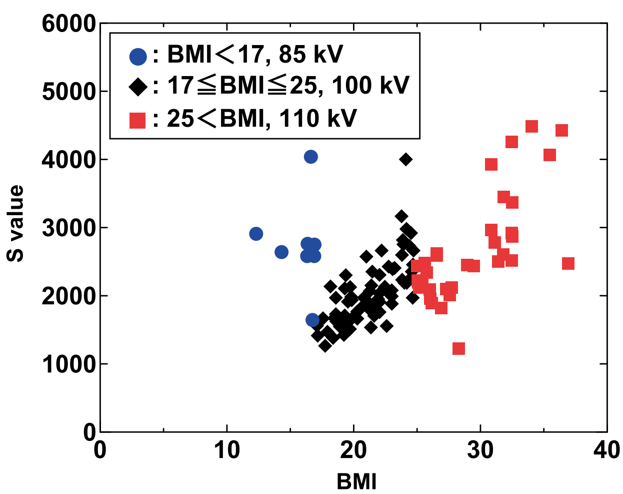

Fig.7 Relationship between BMI of Patients and S-Value of Acquired Images

Dose Comparison

	kV	mA	ms	Time (s)	Cu (mm)	Dose (mGy)
Dynamic breath-holding	100	80	8	7	0.2	1.24
Frontal chest	120	160	20	-	0.1	0.12
Lateral chest	140	125	63	-	0.1	0.40
					Total	0.52

IAEA Guidance Level	Dose (mGy)	Medical Exposure Guidelines by Japan Association of Radiological Technologists	Dose (mGy)
Frontal chest	0.4	Frontal chest*	0.3
Lateral chest	1.5	Lateral chest**	0.8
Total	1.9	Total	1.1

*DRLs2015 ** Medical exposure guidelines 2006

Fig.8 Comparison of Measured Data and Guideline Values

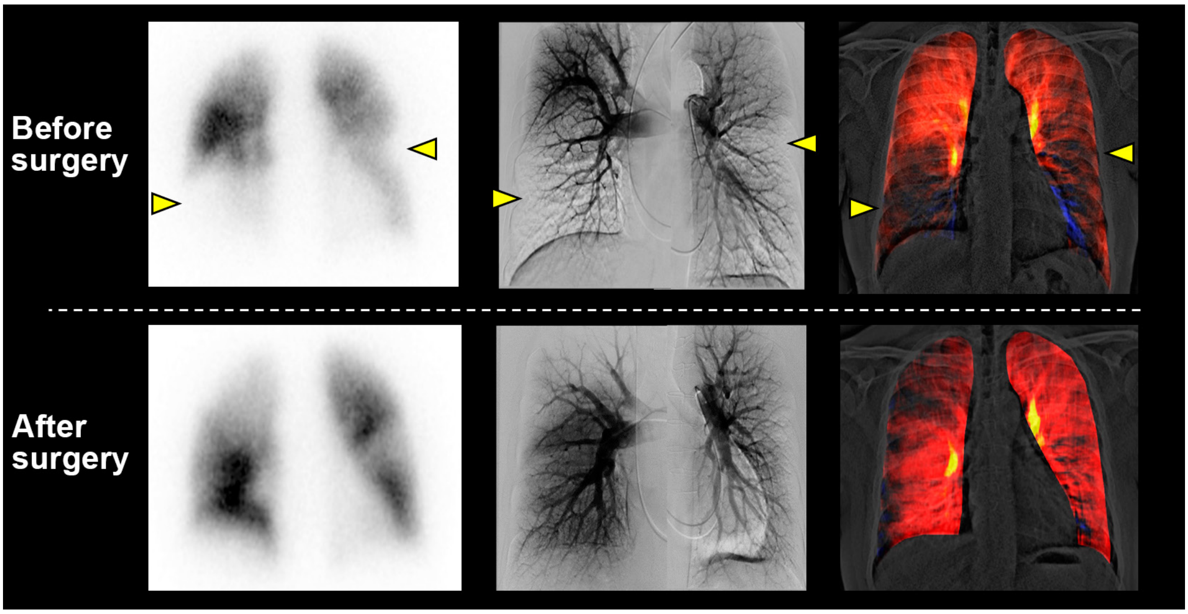

Fig.9 Images of CTEPH Patient Acquired by Different Examination Methods

and lateral views). For reference, we also compared this result obtained using the breath-holding protocol to guidelines established in Japan. The 1.24 mGy ESD measured for dynamic chest radiography was slightly higher than the 1.1 mGy ESD total for frontal and lateral chest views that appears in Japanese guidelines.

We have only just started seeing clinical applications of dynamic chest radiography, hence further study is needed to quickly establish standard exposure conditions for this imaging method. Further study is also needed into the validity of a simple X-ray dose comparison with plain chest radiography.

7. Work at Kyushu University Hospital

More than 180 image acquisitions have been performed by RADspeed Pro style edition and dynamic chest radiography system since its introduction (as of September 4, 2020). Described below are two cases in which the system demonstrated its usefulness.

Fig. 9 shows Tc-99m MAA lung perfusion scintigraphy images (left), pulmonary angiography images (middle), and dynamic chest radiography images (right) from a patient diagnosed with chronic thromboembolic pulmonary hypertension (CTEPH)[3]. The preoperative Tc-99m MAA lung perfusion scintigraphy image shows multiple perfusion defects in both lung fields, which are also visible in the pulmonary angiography image (▷). A pulmonary circulation image generated from the dynamic chest radiography also shows similar findings. The bottom row in Fig. 9 shows images acquired by respective examinations after the patient underwent pulmonary endarterectomy (PEA). After PEA, the pulmonary hypertension was improved and all examination results revealed improved pulmonary blood flow in both lower lung fields. This shows that images of pulmonary circulation image obtained by dynamic chest radiography can potentially be used to assess pulmonary circulation in patients with CTEPH.

Next, Fig. 10 shows lung ventilation and perfusion scintigraphy images (top left: ventilation, top right: perfusion) and dynamic chest radiography images (bottom left: ventilation, bottom right: pulmonary circulation) from a patient examined for shortness

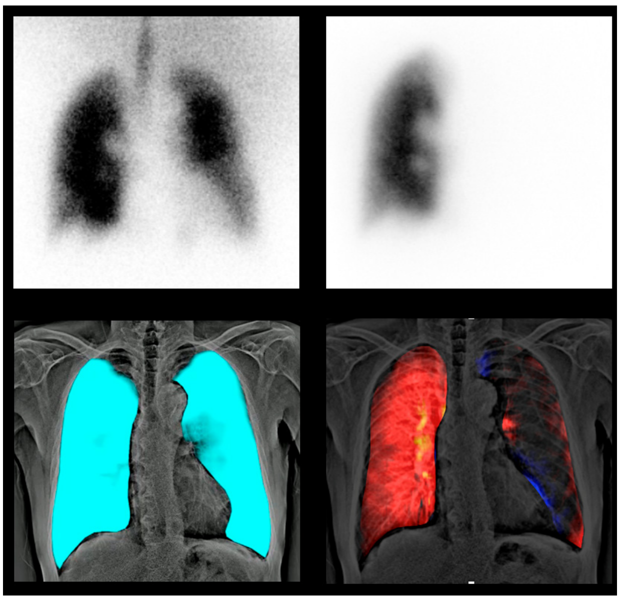

Fig.10 Images of Patient Diagnosed with Blockage of the Left Pulmonary Artery

of breath on exertion[4]. Dynamic chest radiography images reveal a pulmonary ventilation-perfusion mismatch in the left lung and the lung ventilation-perfusion scintigraphy images show similar findings. Based on further examinations, the patient was diagnosed with blockage of the left pulmonary artery caused by vasculitis. These findings show that dynamic chest radiography can potentially visualize even small pixel value changes caused by filling of the lungs with air during respiration (ventilation image) and blood supply during breath-holding (pulmonary circulation image) , without the need for contrast media or radioisotopes (radionuclides).

8. Conclusion

This article describes our experience using a RADspeed Pro style edition digital radiography system and dynamic chest radiography system newly installed at Kyushu University Hospital. Compared to angiographic examinations and nuclear scanning, dynamic chest radiography is a simpler imaging method but can potentially achieve equivalent diagnostic results. Although further clinical studies are needed to demonstrate the utility of dynamic chest radiography, it promises to be a useful alternative diagnostic tool for clinics unable to perform angiographic examinations or nuclear scanning and for medical sites in developing countries.

References

1) Matsutani N. Visualization and Quantitation of Physiological Function by Dynamic Analysis—the Next Stage in Plain Radiography— JIRA Technical Report, 29 (2), 2019
2) IAEA, 1996. International Basic Safety Standard for Protection against Ionizing Radiation and for the Safety of Radiation Source.Safety Series No.115.
3) Yamasaki Y et al. A novel pulmonary circulation imaging using dynamic digital radiography for chronic thromboembolic pulmonary hypertension. European Heart Journal, 41 (26), 2020
4) Yamasaki Y et al. Pulmonary ventilation–perfusion mismatch demonstrated by dynamic chest radiography in giant cell arteritis. European Heart Journal, 2020.

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