

《原 著》

Evaluation of Superimposed Radioisotope and X-ray Image

Kohei SENDA* and Masao KANEKO*

**Department of Radiology, Hamamatsu University School of Medicine, Hamamatsu, Japan*

ABSTRACT A radioisotope image superimposed on an X-ray picture in a film with identical positioning and magnification, which was succeeded by the aid of specially made devices, was evaluated fundamentally and clinically.

Magnification of the X-ray image taken by an X-ray apparatus with a focus to film distance of 306.5 cm was 1.043 in the position of 10 cm above an imaging table. Then, magnification of the radioisotope image was changed to a value of 1.043 by means of adjusting a life-sized imaging device. Two centers of both images were made to coincide with each other by help of a specially made imaging table which enabled a patient to be transported automatically around 90 degrees between two centers of the field of view of a scinticamera and a film cassette holder. On phantom experiment, both images were almost corresponded with each other in position and magnification independently of the position of image sources above the imaging table.

Clinically, the technique showed exactly the internal anatomical relationship between an organ or a tissue imaged by radioisotope and its surrounding structures or a complementary indicator imaged by X-ray. And, morphological and functional informations acquired from the superimposed image was more sensitive and accurate than that from a radioisotope image alone.

I. Introduction

Radioisotope image obtained by the scinticamera is often vague in order to know the anatomical relationship of an organ or a tissue imaged to its surrounding structures. Therefore, various techniques^{1~4)} have been proposed to resolve the handicaps.

We are successful in taking an X-ray picture superimposed on a radioisotope image in a film with identical positioning and magnification by the aid of commercialized and specially made devices.

The purpose of the present paper is to evaluate the superimposed imaging fundamentally and clinically.

II. Materials and Methods

Instrument for the imaging consisted of an

Anger-type scintillation camera (Toshiba, Model GCA-401), an X-ray apparatus (Toshiba, Model DRX-190A and KXO-15), a life-sized radioisotope-imaging device (Toshiba, Gamma Imager Model GMI-04A) and a remote-controlled imaging table (specially designed type).

The scinticamera used had a large field view of about 35 cm in diameter and an overall resolution of 3.2 mm for Tc-99m using a low energy high resolution collimator with parallel 42,000 holes (Toshiba, Model RDH-627). And, movement of the detector-head of scinticamera was designed to control remotely in order not only to diminish the exposure dose of technicians, but also to perform the superimposed imaging readily.

An X-ray tube was fixed in the ceiling in the height of over 310 cm just above the center of a film cassette holder which was fixed 15 cm under the imaging table, obtaining a focus to film distance of 306.5 cm (Fig. 1).

The film cassette was constructed with two intensifying screens attached on both sides of an X-ray film so as to be efficiently radio-graphed and to diminish the exposure dose of patients

受付：56年5月15日

最終稿受付：56年9月3日

別刷請求先：浜松市半田町 3600 (☎ 431-31)

浜松医科大学放射線医学教室

金子昌生

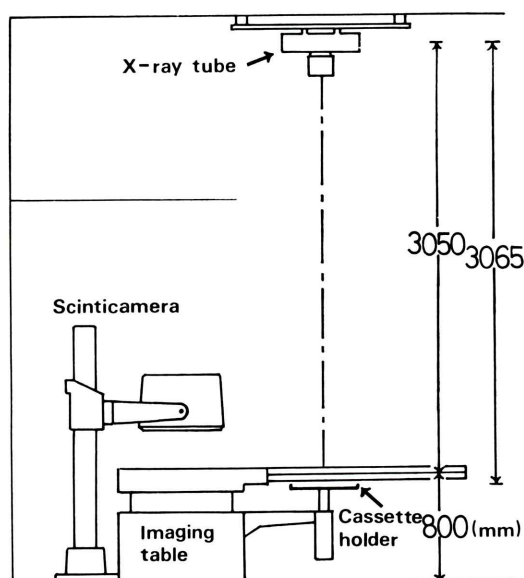


Fig. 1 Geometrical relationship between X-ray tube, imaging table and film cassette holder.

because of decreased out-put of X-ray.

The remote-controlled imaging table was able to turn around automatically 90 degrees between two centers of the field of view of the scinticamera and the film, transporting a patient who was instructed not to move during the procedure.

Tc-99m labeled radiopharmaceuticals were used as radioisotope imaging agent in the majority of subjects. Approximately 20 mCi of Tc-99m was injected to a patient, who was given a blood pool, liver or bone scintigraphy, in order to obtain high quality of radioisotope image with whole accumulated count of more than 500,000. And, the patient was instructed to hold his breath in moderate or maximum level of the inspiration for less than 25 seconds so as to limit a respiratory movement of the organ in the chest or the abdomen.

Following the radioisotope imaging, the X-ray image was taken on the same film at 50 to 70 KVp, 200 mA and 1 second with a grid placed on the film cassette. In this time, the patient was also recommended to hold his breath in the same inspiratory level as on the scintigraphic procedure.

Discrepancy of magnification between the

radioisotope and the X-ray image was examined in a phantom experiment, using point sources of Tc-99m-pertechnetate put into small plastic containers arrayed after the fashion of checkers. Magnification of the radioisotope image was adjusted by means of operating a cathode ray tube in the life-sized imaging device.

The clinical usefulness was evaluated in 120 cases in which the superimposed imaging had been performed. These consist of examining 6 thyroid, 10 blood pool, 54 hepatic, 2 pancreatic, 9 renal, 4 adrenal, 25 bone, and 8 lymphnode and 2 tumor cases. The superimposed images were taken mostly by an anterior projection of view and occasionally by other projections.

III. Results

Magnification of an X-ray image taken by the phantom experiment was 1.027, 1.043 and 1.064 in the height of 5, 10 and 15 cm above the imaging table, respectively. Consequently, difference of magnification between two X-ray images at 5 and 15 cm was calculated to be a negligible value of about 3.5%. And, change in magnification, which involved with bending of the imaging table due to patient's body weight, was measured to be less than 1% in the maximum.

Magnification of the radioisotope image was easily changed to 1.043 which value corresponded to that of the X-ray image. And, two centers of both images were accurately corresponded with each other by help of the specially made imaging table. Consequently, the position and magnification of both images in a film were significantly corresponded with each other independently of the position of image sources above the table on the phantom experiment (Fig. 2).

Exposure dose to patients from X-ray was measured to be the values of 412 mR to 902 mR in air at the above-mentioned exposure factors in the position of 5 cm above the table.

Clinical usefulness of the superimposed imaging was recognized in many cases that had to evaluate the size, position or configuration of an organ or a space occupying lesion. Size of an organ or a tissue imaged by radio-isotope was accurately evaluated in comparison with patient's physique or structure delineated by X-ray. This finding on size was useful to know a pathological change in

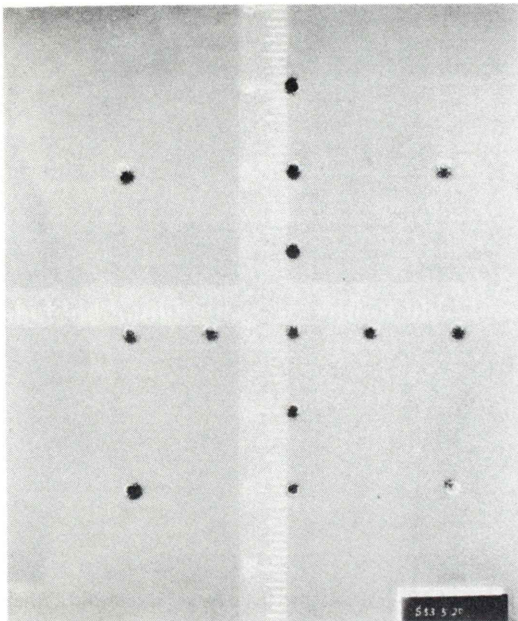


Fig. 2 Phantom experiment using point sources of ^{99m}Tc -pertechnetate in small plastic containers arrayed after the fashion of checkers.

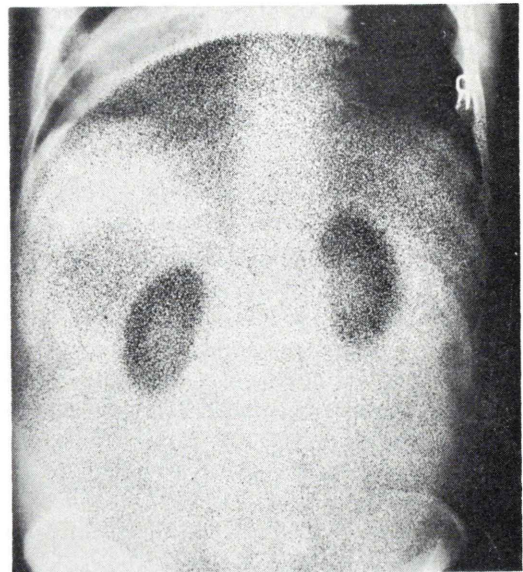


Fig. 3 RIX-gram of the kidneys in a 73-year-old male with atrophic kidneys. It was taken in the posterior view 3 hours after intravenous injection of 5 mCi of ^{99m}Tc -DMSA, holding his breath in maximum inspiration.

size of the organ in 5 cases with enlargement or shrinkage of the liver or the kidney and in 7 cases with cardiac dilatation or pericardial effusion. In a case of bilateral renal atrophy for example, radioisotope images of both kidneys were apparently small in size in contrast to the X-ray image of the patient's physique (Fig. 3). And, in a case of pericarditis, the "Halo" or "U" sign of very low radioactivity area of horse-shoe shape, surrounding a high radioactivity area of the intracardiac blood pool, was obviously visible through the enlarged cardiac silhouette delineated by X-ray (Fig. 4).

Position of an organ or a tissue imaged by radioisotope was exactly depicted on a superimposed X-ray image of the body. These findings on position were helpful to know accurate position of a lesion or pathological shift of the organ in 19 cases with malignant tumor of the thyroid, the liver and the bone. These findings were also helpful to decide a location of radiation field in therapy. In a case of thyroid cancer, metastatic lesions showing abnormally high uptake of I-131 were detected exactly in a position of palpa-

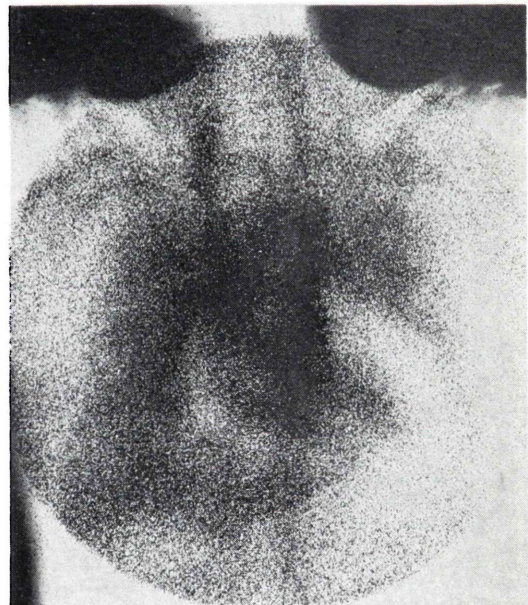


Fig. 4 RIX-gram of the heart in a 73-year-old male with pericardial effusion. It was taken in the anterior view 5 min after intravenous injection of 20 mCi of ^{99m}Tc -HSA, holding his breath in maximum inspiration.

ble facial tumors, lateral contours of which were delineated on the superimposed X-ray image (Fig. 5). In the same way, position of malignant imaged by Ga-67-citrate was exactly confirmed on the X-ray image of the chest, the abdomen or the bone.

In the case of liver cirrhosis with relaxatio diaphragmatica, elevation of the right lobe of the liver was obviously demonstrated just under the elevated right hemidiaphragm (Fig. 6). It was also helpful to diagnose a subdiaphragmatic mass lesion in two cases. And, in a case of gastric cancer with carcinomatous peritonitis, radioisotope image of the liver revealed remarkable displacement probably due to ascites (Fig. 7). Three of four cases with ascites were diagnosed as peritonitis by the help of the superimposed image.

Marginal space occupying lesion of an organ imaged by radioisotope was able to be easily disclosed and measured by means of comparison with

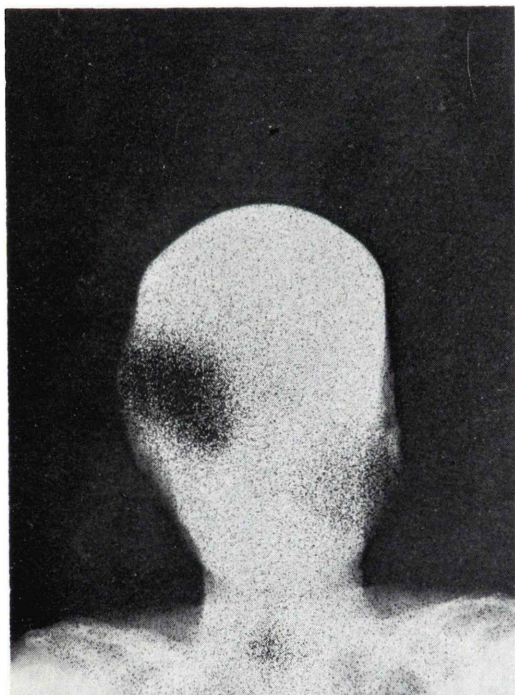


Fig. 5 RIX-gram of metastatic head tumors in a 63-year-old female with thyroid cancer. It was taken in the anterior view 10 days after oral administration of 20 mCi of ^{131}I -Na for the purpose of radiation therapy.

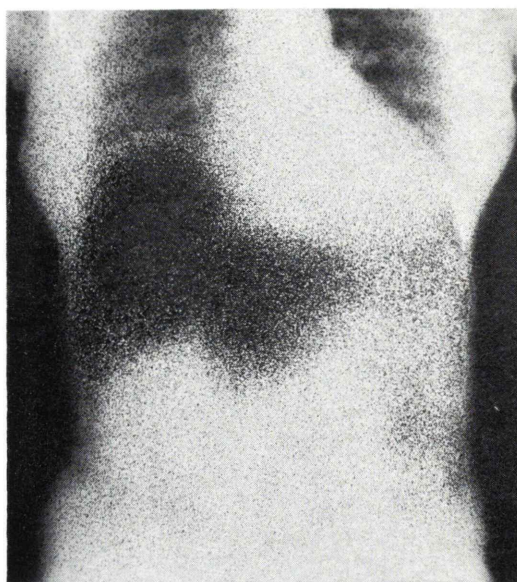


Fig. 6 RIX-gram of the liver in a 58-year-old female with liver cirrhosis. It was taken in the anterior view 20 min after intravenous injection of 15 mCi of $^{99\text{m}}\text{Tc}$ -phytate, holding her breath in maximum inspiration.

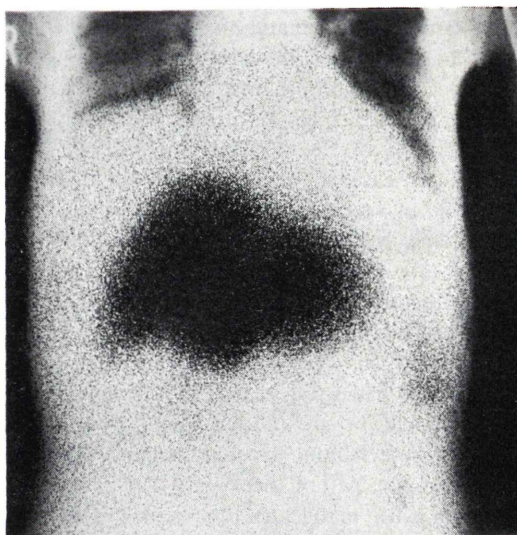


Fig. 7 RIX-gram of the liver in a 73-year-old female with gastric cancer. It was taken in the anterior view 20 min after intravenous injection of 20 mCi of $^{99\text{m}}\text{Tc}$ -phytate, holding her breath in maximum inspiration.

the superimposed X-ray image that showed the organ itself, its surrounding structure and a complementary indicator attached on the body surface. These findings on detecting a space occupying lesion were valuable to disclose the lesion as small as possible in 13 cases with tumor or abscess of the liver. In a case of gastric cancer with liver metastasis, marginal metastatic lesions of the liver were exhibited as a small cold area just under the right hemidiaphragm and as an egg-sized cold area at the lower edge of the left lobe, which was surrounded inferiorly by the X-ray image of a leaden string (Fig. 8). This leaden string had been attached along the edge of a firm epigastric tumor which was palpable in the left hypochondrium. And, in a case of Wilm's tumor given Co-60 irradiation of 2250 rad, a cold area of radioisotope liver image, which corresponded exactly to the radiation field over the liver, was clearly demonstrated in the liver shadow by X-ray (Fig. 9).

In addition, the superimposed image enabled various findings on radioisotope images to be compared accurately with those on other X-ray images obtained by roentgenographic procedures, such as gastrointestinal radiographic examination, angiography or lymphography. These scintigraphic findings comparable with roentgenographic findings obtained by using contrast media were significant to diagnose or investigate some detail of lesions in 11 cases with malignant tumor of the liver, the adrenal or the lymph-nodes. In a case of cancer of the urinary bladder, radioisotope image showed the iliac and inguinal lymph-nodes to be cold in the region of lymph-node metastases which were confirmed precisely on lymphography by Kinmonth's method in comparison with the finding on the superimposed image. And, in this case an irregular filling defect of the urinary bladder imaged by radioisotope was exactly corresponding to that detected on cystography.

These findings were also helpful for radiation therapy, especially, decision of radiation field in the light of X-ray image of the patient's physique, the skeleton and the soft tissue in 7 patients who were given a radiation therapy.

IV. Discussion and Conclusion

Morphological diagnosis in nuclear medicine is useful for its characteristic that is essentially func-

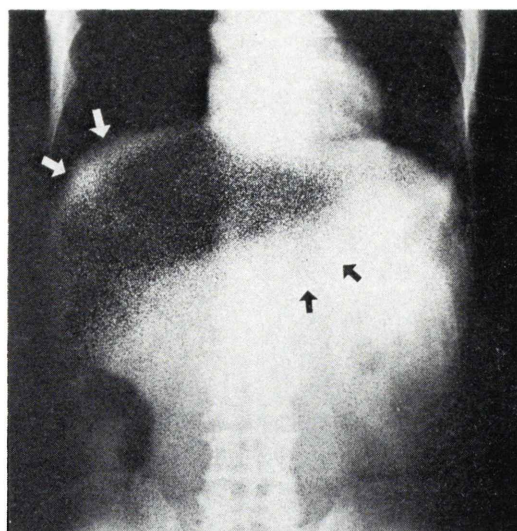


Fig. 8 RIX-gram of the liver in a 80-year-old male with gastric cancer. It was taken in the anterior view 20 min after intravenous injection of 20 mCi of ^{99m}Tc -phytate, holding his breath in maximum inspiration. Black and white arrows indicate a leaden string and a small cold area, respectively.

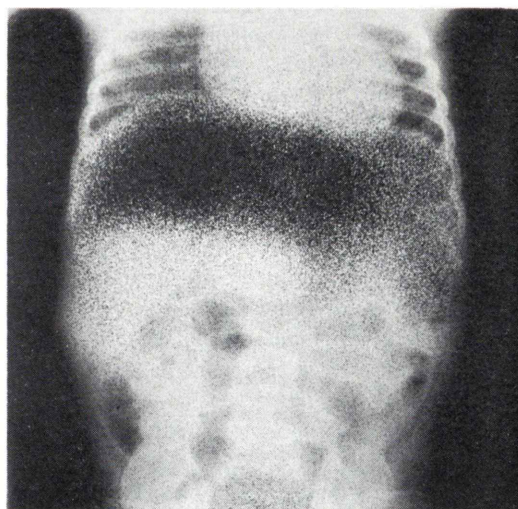


Fig. 9 RIX-gram of the liver in a 1-year-old male with Wilm's tumor of the right kidney given ^{60}Co irradiation. It was taken in the anterior view 20 min after intravenous injection of 3 mCi of ^{99m}Tc -phytate.

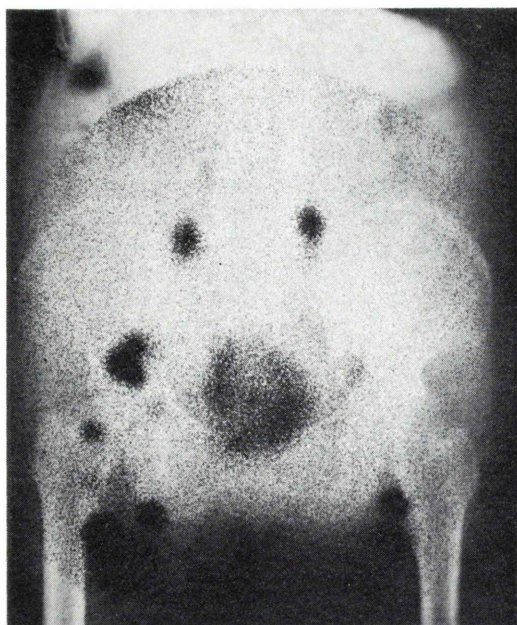


Fig. 10 RIX-gram of the lymph nodes in a 74-year old female with cancer of the urinary bladder. It was taken in the anterior view 3 hours after subcutaneous injection of 5 mCi of ^{99m}Tc -phytate bilaterally to the back of both feet.

tional study. However, radioisotopic image obtained by scinticamera is often obscure to confirm the anatomical relationship of a lesion. Morphological findings on scintigraphy are frequently referred to those on other imaging studies in order to confirm location, size or configuration of an organ or a space occupying lesion. For the purpose of the confirmation, it is necessary to know the anatomical relationship of an organ or a tissue imaged by radioisotope to its surrounding structure which are imaged complementally by other procedures. Some techniques^{1~3)} therefore have been proposed to obtain a complementary information. In the scanning procedure, outlines of the body or marked points on the body surface, which are easily drawn on a scintigram, are clinically useful to know the external anatomical relationship of the scintigram. And, even for the scinticamera images, external marking method using a electronic device, which Walton and Sharpe²⁾ worked out, are utilized to obtain the complementary informations. These techniques however are limited to know

the internal anatomical relationship of the organ imaged.

In the techniques using scinticamera, transmission-emission scintigraphic technique³⁾ is prevailing to date because it is convenient and reliable procedure. But, this technique is also limited to know exactly the internal anatomical relationship.

On the other hand, a technique as superimposing a scintigraphic with a roentgenographic film, which were taken separately during a some interval of time, was used as initial attempt¹⁾ for this purpose. This technique necessitates no special devices and is very convenient. But, it is inaccurate in order to show the anatomical relationship because of its several disadvantages resulting from unhelped difference in the position of patient between the two procedures, considerable difference in magnification of the two pictures, and physiological motion such as respiratory movement of the subject imaged.

However, if these disadvantages would be overcome by any adequate devices, the superimposed technique combining radioisotope with X-ray image will be more exact than other conventional techniques in order to know the internal anatomical relationship, where the surrounding organs and tissues or the organ itself could be finely demonstrated by X-ray. Then, we got satisfactory results in the basic and clinical studies in which accurate superimposition of the radioisotope and the X-ray images was obtained using identical procedure. The technique of taking such a superimposed radioisotope and X-ray image be called as RIX-graphy in the previous work by Kaneko and his coworkers⁴⁾. In this paper, further studies on the procedure and clinical studies using the ideal instrument were carried out in order to apply the technique to clinical practice.

Theoretically, it is impossible to use the parallel hole collimator for this imaging technique because magnification of an X-ray image depends on the distance from a film. However, magnification of an X-ray image taken by our devices was so small and magnification of a radioisotope image through the parallel hole collimator was so appropriately adjustable that the two images in a film were almost always constant in size independently on the depth of the imaged subject in the body.

In RIX-graphy, it is necessary to transport a

patient between centers of the two imaging devices and to be constant in geometrical relationship between a patient and both imaging devices. This troublesome was improved by means of using a specially made imaging table in our studies. The time required for RIX-graphy was 5 to 10 minutes, greater part of which was used to transfer a film cassette holder.

It was a problem that physiological movement of the organ and tissue affected the anatomical relationship between both images in a RIX-gram. Then, a patient who was given an abdominal or chest RIX-graphy after injection of about 20 mCi of Tc-99m-labelled radiopharmaceutical was instructed to hold his breath in moderate or maximum inspiration for less than 25 seconds during radioisotope imaging and for less than several seconds on X-ray imaging so as to obtain positional correspondence between both images as precisely as possible.

On the other hand, RIX-graphy has a disadvantage of X-ray exposure to the patient in addition to an exposure from radionuclide. Then, it is necessary to make efforts to reduce X-ray radiation and radionuclide administration dose, and so to consider the indication for this technique. Consequently, this technique has to be applied when the morphological and functional confirmation on radioisotopic imaging is particularly worthwhile in clinical diagnosis or treatment of malignant lesions. From this point of view, approximately 40 cases which were all the patient with malignant

tumor of the liver, the bone and the lymph-node were truly significant to perform the superimposed imaging. The number of significant cases accounted 33% of all cases of subjects and 73% of cases in which the superimposed imaging was more valuable than the radioisotope imaging alone.

Acknowledgement

We are very indebted to Mr. S. Sakamoto and Mr. K. Morozumi, Hamamatsu University Hospital, for their help.

The present work was originally presented at the 2nd International Congress of World Federation of Nuclear Medicine and Biology in Washington, D.C., in September 1978, and then at the 38th Annual Meeting of Japanese Society of Radiology in Tokyo in March 1979.

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要 旨

RI および X 線重複画像の評価

仙田 宏平* 金子 昌生

浜松医科大学放射線医学教室 (*現在 名古屋大学医学部放射線医学教室)

シンチカメラによる RI 画像は描出組織とその周囲組織との解剖学的関係を明確に表示できない欠点がある。体内 RI 分布の位置や拡がりを的確に描出することは形態診断のみならず機能診断にも意義が大きい。そこで、RI 画像を X 線画像と同一位置および拡大率で 1 枚のフィルム上に重ねて撮像できる装置ならびに方法を実用化したので、その有用性を基礎的ならびに臨床的に検討した。ファントム実験で、撮像用テーブル上 10 cm の X 線画像の拡大率は約 1.04 となり、その上下 5 cm における拡大率差は約 1.7%であった。RI 画像の

大きさをこの拡大率に合うよう調節したところ、両画像の幾何学的関係は撮像対象物の位置と無関係にほぼ一致した。各種シンチグラフィを行った 120 症例に応用したところ、臓器の位置や大きさ、腫瘍病変の位置や拡がりなどを検出するうえに従来の RI 画像と比べて的確であり、内 40 症例で RI 画像診断能の向上に特に有用な結果が認められた。

Key words: Superimposition of images, Radioisotope and X-ray image