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Authors
McRae, James
Anger, Hal O.

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University of California

Ernest O. Lawrence
Radiation Laboratory

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James McRae* and Hal O. Anger

Donner Laboratory and Lawrence Radiation Laboratory
University of California, Berkeley, California

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ABSTRACT

Clear transmission pictures have been obtained of the heart, diaphragm, trachea, and the lungs in both PA and lateral projections, using the scintillation camera and a radioactive source on the opposite side of the patient. Gas within the stomach and bowel is visualized, and contrast media is readily seen in the intestine.

Transmission scintiphotos are of use in the interpretation of the conventional emission scintiphotos. For example, transmission pictures define the extent of the lung so that lung perfusion studies can be interpreted properly. They show the position of the diaphragm in liver studies so that space-occupying lesions between the liver and diaphragm can be detected. They are also useful in positioning the heart and lung fields for dynamic tracer studies.

The use of transmission scanning with a rectilinear scanner as a means of improving the interpretation of radionuclide emission scans has been reported previously by Kuhl et al. and it has also been used by Anger in the Whole Body Scanner Mark II.

To take transmission images with the scintillation camera, a conventional multichannel collimator is placed on the camera and a radioactive disc source 11 inches in diameter is placed underneath the patient. A second multichannel collimator is placed on top of the source to reduce the radiation dose to the patient. It also reduces the amount of scattered radiation that appears on the pictures. If the disc source contains about 10-20 mCi of ^{99m}Tc, transmission pictures can be taken in 1-2 minutes. The patient receives less than 1 milliroentgen per hour to a limited area of the body and virtually no irradiation elsewhere.

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*Presently on sabbatical leave from Department of Medicine, University of Sydney, Australia.

The 140-keV gamma rays from technetium have very little selective absorption in bone, compared to lower-energy gamma rays and x-rays. They are scattered by all tissues, and therefore are useful for imaging air spaces within the body such as the lungs. Defects in these air spaces, such as large solid space-occupying lesions in the lungs, can also be visualized.

Transmission pictures can be used in positron-camera studies. Instead of a disc source, a radioactive point source is placed at the same distance from the image detector as the positron-camera focal detector crystal. No collimators are used. Transmission scintiphotos are then obtained that have the same magnification as the positron emission pictures.

INTRODUCTION

The use of transmission scans taken with a rectilinear scanner as a means of improving the anatomical orientation and interpretation of emission scans has been reported by Kuhl et al. [1] and the technique has been used by Anger [2] in the Whole Body Scanner Mark II to outline the body and the lungs. We now obtain transmission pictures of the lungs, diaphragm, and heart in all projections by using the scintillation camera with a radioactive source on the opposite side of the patient [3].

At times there are difficulties in relating conventional emission scans and scintiphotos obtained after the administration of radioactive pharmaceuticals to the anatomy of the patient. Radioactive and radio-opaque markers, optical photographs of the region, and standard radiographs have been used. Transmission pictures are an additional convenient aid in interpreting emission scintiphotos; they are in correct proportion and are obtained in the same position as the emission study. The air spaces in the body are seen as areas of increased transmission. The lungs and borders of adjacent organs are clearly delineated. Gas within the stomach and bowel is visualized and carbonated beverages can be used to outline the stomach and help locate the lower border of the liver. Major soft tissue masses reduce transmission but bony detail is not shown. Key landmarks such as the sternal notch in thyroid scintiphotography and the costal margin in liver studies are usually located with radioactive or lead markers during emission studies, but lead absorbers have also been used with effect during transmission studies. Barium contrast agents can be seen in the intestine.

METHOD

To take transmission pictures with the scintillation camera, either a point source or an extended source is used, depending on the collimation method to be used in taking the emission picture. When a multichannel collimator is to be used on the scintillation camera, a radioactive disc source 11 inches in diameter is positioned underneath the patient (Fig. 1) directly opposite the image detector. The disc is shielded on the botton and sides. A second multichannel collimator is placed on top of the source to reduce the radiation dose to the patient by defining the field and removing radiation which is not parallel with the channels of the image collimator. A low-resolution collimator is adequate for this purpose. Trials were made with high-resolution collimators overlying the disc source with

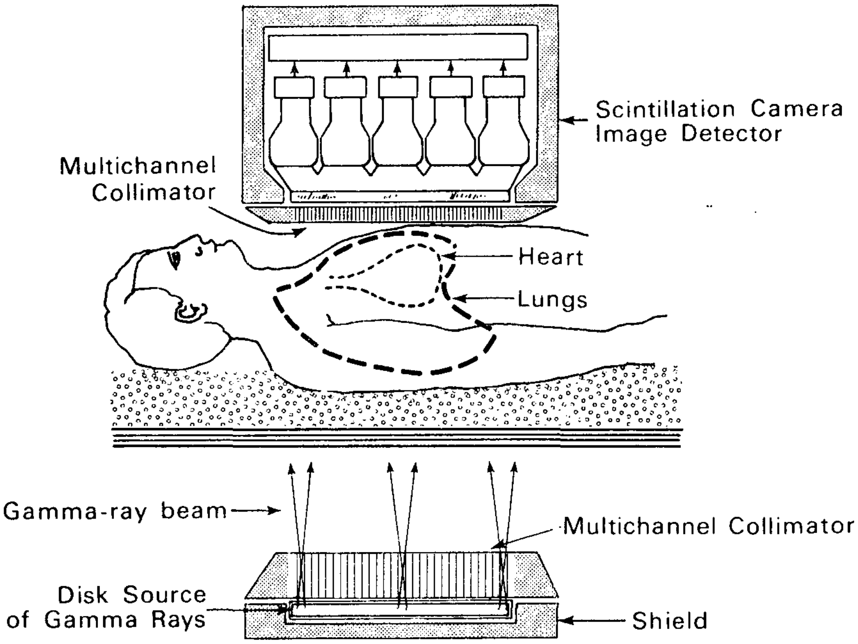

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Fig. 1. Technique for taking transmission scintiphotos by using a disc source.

a marginal improvement in resolution and contrast of the pictures. The distance between the patient and the disc source is not critical, but the image detector and its collimator should be as close to the patient as practical.

In general we use 15-25 mCi of ^{99m}Tc in the disc. Excellent transmission pictures of the chest with 200 000-400 000 counts can be obtained in 1-2 minutes. When breath-holding studies are performed, 50-100 mCi can be used to reduce the exposure time without saturating the camera. The 140-keV gamma rays from technetium have very little selective absorption in bone compared with x-rays and gamma rays of lower energy. At this and higher gamma-ray energies the principal contrast is between tissue and air spaces [4]. The patient receives less than 1 milliroentgen per hour to the area of the body within the gamma-ray beam and virtually no irradiation elsewhere. The transmission disc source can be covered with a lead plate 1/4-inch thick when it is not being used. ^{57}Co with a half life of 270 days and energy 0.122 and 0.136 keV could be substituted.

With positron coincidence cameras a slightly magnified image of the subject is formed at the image detector crystal. To produce transmission pictures with identical magnification, a radioactive point source is used. The source is placed at the same distance from the image detector as the positron-camera focal-detector crystal. No collimators are used. The source is housed in a lead shield so that an area only slightly larger than the image detector is irradiated. ^{139}Ce has proved very satisfactory because of its energy (160 MeV) and half-life (140 days). A 250-μCi point source allows pictures to be taken in 1-2 minutes. Point source pictures do not have as good contrast as those obtained with a collimated disc, because more scattered radiation that cannot be entirely eliminated by pulse-height selection reaches the image detector.

The quality and relative merits of transmission scintiphotos obtained by using radioisotopes with gamma rays with energies less than and greater than ^{99m}Tc were explored. Point and disc sources of ^{125}I, ^{197}Hg, ^{99m}Tc, ^{203}Hg and ^{113m}In were evaluated. In addition, point sources of ^{241}Am, ^{139}Ce, and ^{133}Ba were compared with one another.

A disc source containing 40 mCi of ^{125}I (30 keV) produced chest pictures with satisfactory resolution and excellent contrast, but even in thin subjects the exposure time required for 100 000 dots was 5 minutes due to the low count rate. There was contamination of the ^{125}I with ^{126}I (0.386 and 0.667 keV) which contributed significantly to the count rate. Large bones such as the femur and tibia could just be distinguished but bony detail could not be shown with either a disc or point source. Relatively poor inherent resolution of the camera at this energy is partly responsible.

Likewise, no additional information was apparent in the transmission pictures obtained with either a disc or point source of ^{197}Hg (79 keV) and point source pictures with ^{241}Am (59.6 keV) did not show useful bony shadows.

The higher-energy gamma rays from ^{203}Hg (279 keV), ^{133}Ba (360 keV), and ^{113m}In (400 keV) gave satisfactory transmission pictures showing heart, lungs, and diaphragm. ^{113m}In was used to show the junction of liver and lung after the administration of technetium sulfur colloid; pulse-height selection was employed to eliminate the gamma rays from technetium when the transmission picture was being taken. In general it has proved more convenient to take combined emission-transmission pictures by using ^{99m}Tc in the disc.

When ^{99m}Tc transmission pictures were required after the patient had been given a radionuclide emitting gamma rays with an energy above 140 keV, a multichannel collimator appropriate to the higher energy was used. The most direct correlation was obtained when the emission data were recorded and the transmission picture then superimposed on the same film. This approach is not applicable to studies of the lung but can be employed to show the relation of aerated lung to normal liver in hepatic emission studies. Separate emission scintiphotos are always taken because contrast is reduced in the combined pictures.

In general the emission and transmission scintiphotos were taken during normal respiration. Some studies were performed with breath-holding during one or more intervals. Diaphragmatic movement and regional lung expansion could be observed. There was significant improvement in the sharpness of the borders of the heart and diaphragm, particularly with breath-holding in deep inspiration.

External metallic objects such as lockets and coins produce shadows and should not be allowed within the camera field. Lead markers were used to locate key bony landmarks.

APPLICATIONS

Transmission scintiphotography has become part of our routine in studies of the liver, lungs, and heart. It is helpful to be able to position the patient with certainty prior to a dynamic study which cannot be repeated and the technique is proving of especial value in centering the heart or a lung lesion for dynamic tracer studies.

Whenever a liver scan is requested because of a radiograph that shows an alteration in the right diaphragm, or when subdiaphragmatic pathology is suspected, transmission pictures with breath-holding in two distinct phases of respiration are taken to show diaphragmatic movement. The radioactive tracer is then injected and an emission scintiphoto obtained before the patient is allowed to move. The emission picture showing the upper border of normal liver and the transmission picture showing the extent of aerated lung are carefully compared to exclude the presence of a lesion between liver and lung. Further combined emission-transmission pictures are taken in different projections.

An alternative is to use an isotope with a different gamma-ray energy for the transmission pictures. Separate exposures are required to record the emission and transmission data which are superimposed on the one film. It is harder to be sure that the patient is in the same position and that respiration is equivalent. If separate pictures are taken, it is advisable to use either a grid for reference or a negative of one film as an overlay when comparing the films.

In lung perfusion and ventilation studies the transmission pictures define the extent of air-filled lung tissue. A most significant finding is an area with the transmission equivalence of normal lung and absent isotope in the perfusion or inhalation emission scintiphoto. The transmission pictures do not show the ribs and individual vertebrae, but additional localization can be achieved by placing lead markers over bony landmarks.

In a patient with a pericardial effusion, comparison of a blood pool scan with a transmission picture of the heart showed a marked discrepancy in size (Gottschalk, personal communication).

The attenuation of the transmission gamma rays is an index of the possible attenuation of the emission rays. Shadows produced by overlying structures and interposed metallic objects are detected. Barium contrast is visualized, and since barium studies are usual in the investigation of the pancreas for space-occupying disease, artifacts could result in pancreatic scintigraphs performed before the barium is excreted.

We have used the point-source technique in ^{82}Rb studies of the myocardium [5]. The subject was positioned correctly by the use of transmission scintiphotos before the short-lived tracer was injected. The outline of the heart, suitably magnified for direct comparison with the positron emission picture, helped in the interpretation of the emission pictures.

The normal findings, points in technique, and the additional information that can be obtained in patients by using transmission scintophotography are illustrated by the following examples.

Four transmission views of the chest of a normal male (J. M.) weighing 150 lb, taken by using a disc source containing 15 mCi of ^{99m}Tc, are shown in Fig. 2. Exposure time was 2 minutes during normal respiration. (A) shows a supine posteroanterior view of the lower chest. The outline of the heart and diaphragm are well shown. In (B) the neck and upper lung fields are seen. The clavicles and pulmonary arteries are visible as areas of slightly diminished transmission. The bright areas above the shoulders result from the direct passage of gamma rays outside the body to the detector. (C) shows a prone anteroposterior projection showing the vertebral column and surrounding soft tissues. The heart and major vessels are less clear because they are farther from the camera in this view. The lower border of the right lung is also not as sharp, because the posteroinferior portion of the lung is tapered. (D) shows a left lateral decubitus view of the lower lung field. The subject is lying on his right side with his arms above his head. The anterior and posterior body walls and the cardiac silhouette are seen but the vertebral column cannot be distinguished. The shadow above the heart is produced by the axillary fold musculature. Lateral transmission scintiphotos, like lateral chest x-rays, are more difficult to interpret because of overlapping shadows.

The additional information to be gained by taking emission and transmission scintiphotos of the lungs and adjacent organs with breath-holding is being explored. PA disc transmission pictures of a normal male (J. M.) taken during deep continuous breathing for 2 minutes (A) and during 4 periods of breath-holding in maximum inspiration for a total of 2 minutes (B) are shown in Fig. 3. There is blurring of the diaphragm with exaggerated

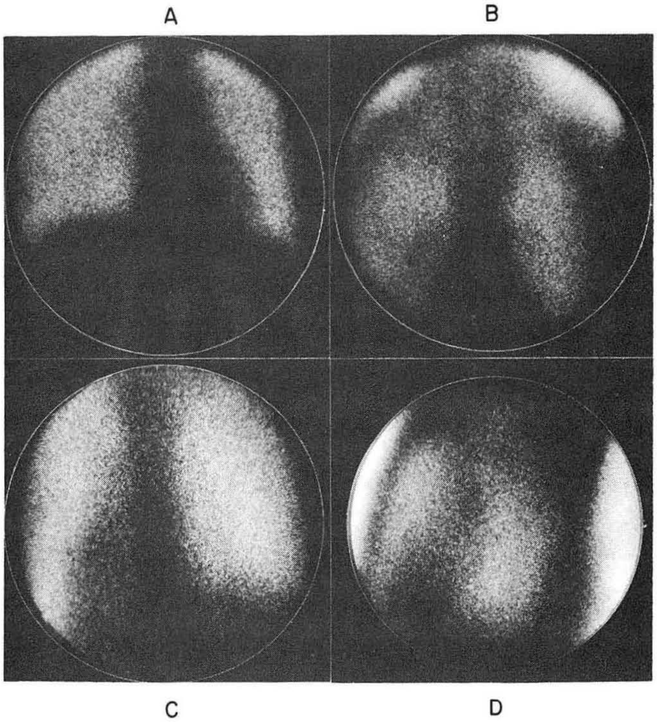

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Fig. 2. Transmission pictures taken with a disc source of ^{99m}Tc, of normal male (J. M.).

A. Heart and diaphragm, posteroanterior view.

B. Upper chest, posteroanterior view.

C. Heart, spinal column, and surrounding soft tissues and part of both diaphragms, anteroposterior view.

D. Middle chest, left lateral view.

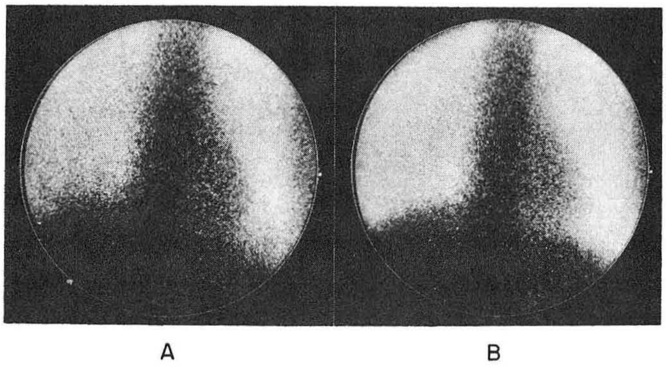

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Fig. 3. Posteroanterior disc transmission pictures of the chest.
A. 2-minute exposure during deep continuous breathing.
B. Exposure during 4 periods of breath-holding totaling 2 minutes.

respiration. When pictures were taken during quiet respiration and compared with photographs taken during breath-holding at one phase of normal breathing, little difference could be detected when the exposure time was 1-2 minutes. More than one period of breath-holding was required to make up the exposure time; failure to breath-hold in the same phase may have been responsible.

When the amount of ^{99m}Tc in the disc was increased to 40 mCi, an adequate number of dots for a good picture could be accumulated in 20-30 seconds. Comparison was made between normal breathing and a single period of breath-holding. There was significant improvement in the sharpness of the borders of the heart and diaphragm.

The improvement in definition to be gained by single 20-30 second exposures with breath-holding in maximum inspiration is illustrated in Fig. 4 in which PA, AP, and lateral views of the chest of a normal male (J. M.) taken during normal breathing are compared with scintiphotos taken with breath-holding.

Pictures taken in two phases of respiration show diaphragmatic movement expansion of the lung and, as in the case illustrated in Fig. 5, interference from an overlapping breast may be avoided. PA disc transmission scintiphotos of the right diaphragm of a female (M. B.) referred for liver scan to exclude hepatoma as the cause for her polycythemia are shown. In (A), taken during quiet respiration, the breast shadow is superimposed on the diaphragm and produces an abnormal appearance. (B), taken with breath-holding in maximum inspiration, shows that the diaphragm moves normally and has a normal curvature. The breast shadow no longer overlaps. The increased transmission at the lung bases and at the cardiac apex is a common finding and may be explained by the absence of thick muscles over the lower chest wall.

The value of a transmission scintiphoto prior to a dynamic study is illustrated in Fig. 6. At top left is the transmission picture of the patient (B. P.) with a large secondary melonoma in the lingula lobe of the left lung. The heart and lesion have been positioned optimally in the field. Five rapid-sequence emission scintiphotos each exposed for 2.5 seconds commencing at the completion of an injection of 2mCi ^{99m}Tc as technetium sulfur colloid into the external jugular vein are shown.

In liver studies using technetium sulfur colloid, combined emission-transmission scintiphotos are used to exclude or define lesions between the liver and lung by using technetium in the disc source. A boy (J. J.) 8 years of age was referred for study 2 weeks after an operation for a ruptured appendix because of continuing fever and roentgenological examinations highly suggestive of a right subphrenic abscess. The camera studies confirmed the presence of a lesion between the liver and the diaphragm and showed a suspicious gap between the left lobe of the liver and the spleen (Fig. 7). At operation, pus was found under the right diaphragm and beneath the left lobe of the liver.

The features of the combined emission and transmission studies were the absence of diaphragmatic movement; a triangular area of absent isotope uptake and transmission between the liver, diaphragm, and lateral

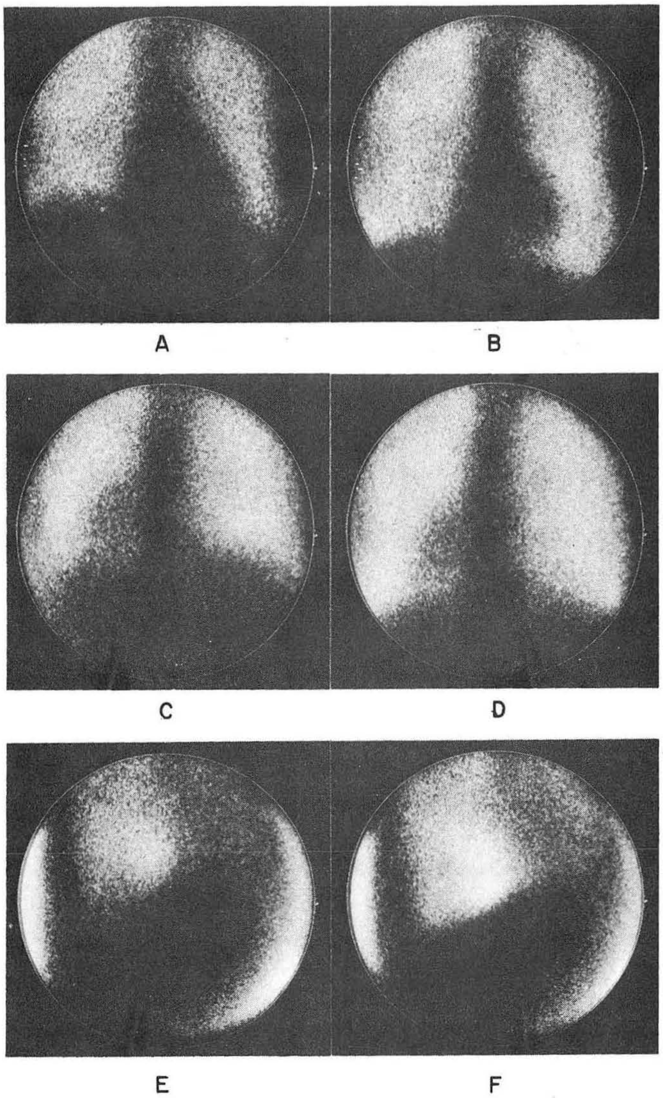

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Fig. 4. Transmission scintiphotos of the chest of a normal male (J. M.) taken during normal breathing and during a single period of breath-holding in deep inspiration.

A&B. Supine posteroanterior views, exposure time 20 seconds.
C&D. Prone anteroposterior views, exposure time 20 seconds.
E&F. Lateral view of lower chest with the subject lying on his left side, exposure time 30 seconds.

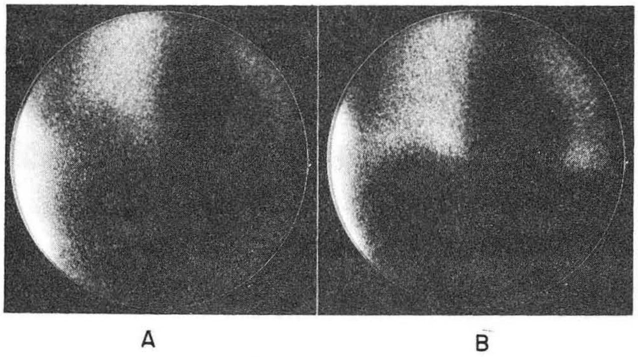

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Fig. 5. PA transmission scintiphotos of the right diaphragm of a female (M. B.) taken in two distinct phases of respiration.
A. Quiet respiration, exposure time 1 minute.
B. Breath-holding in deep inspiration (4 intervals of 15 seconds).
The breast shadow overlaps the diaphragm in A but not in B.

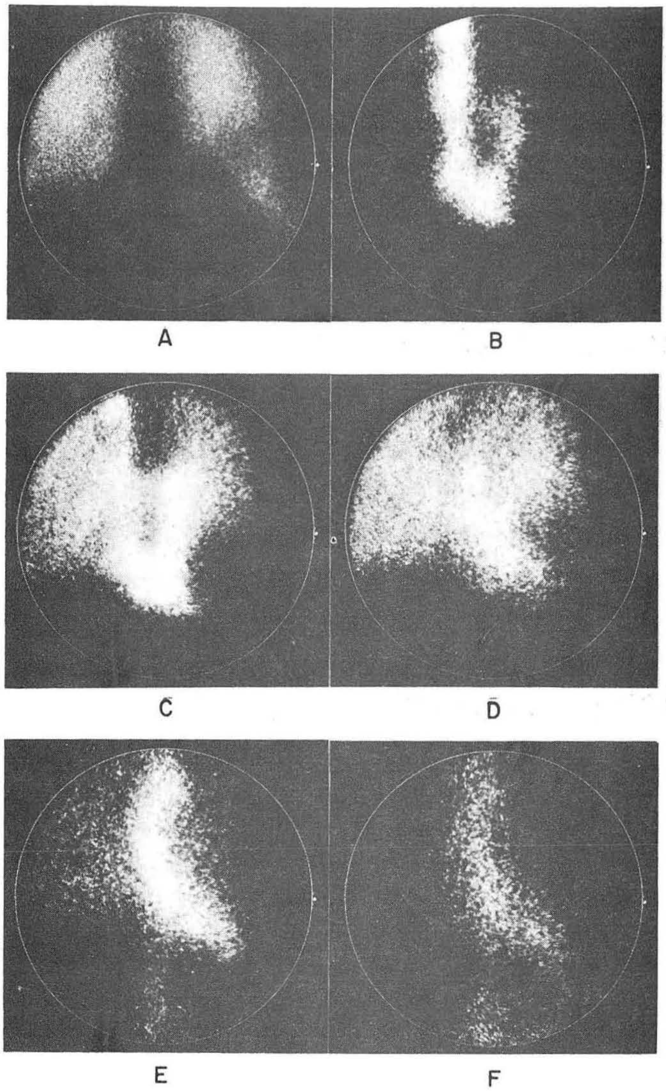

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Fig. 6. PA transmission picture (A) has been used to position the heart and lingula lobe of the left lung which contains a large secondary melanoma prior to a dynamic tracer study. B, C, D, E, F: serial scintiphotos at intervals of 2.5 seconds after the injection of 2 mCi ^{99m}Tc sulfur colloid into the external jugular vein.

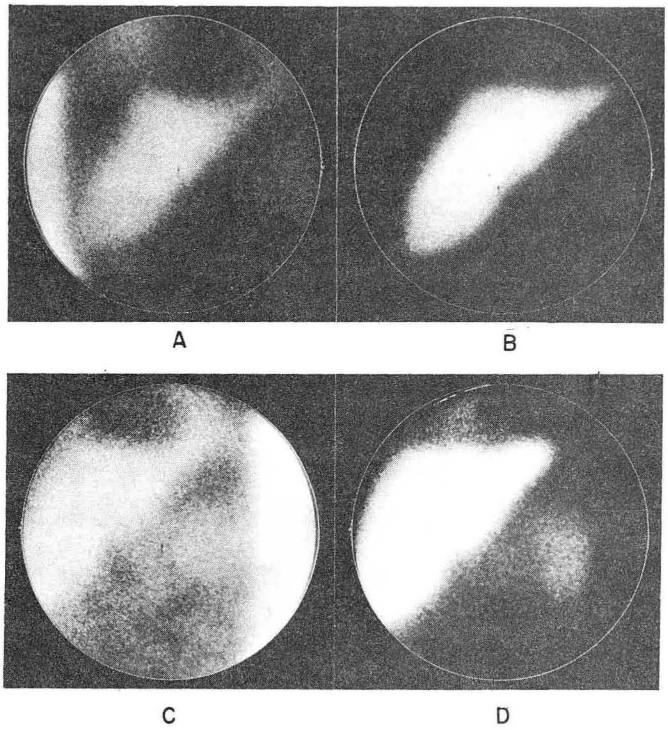

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Fig. 7. Emission-transmission and emission scintiphotos of the patient (J. J.) with a right subphrenic abscess and a second loculus beneath the left lobe of the liver. 2 mCi ^{99m}Tc sulfur colloid and a disc containing 40 mCi ^{99m}Tc pertechnetate were used.

(A) An emission-transmission picture which shows a triangular-shaped area of absent radioisotope uptake and low transmission situated between the liver, diaphragm, and lateral abdominal wall.

(B) Emission scintiphoto showing that the lateral border of the liver is concave opposite this area.

(C) An emission-transmission scintiphoto of the left diaphragm. There is an abnormal area between the tip of the left lobe of the liver and the lung above and the spleen below.

(D) Emission picture which shows the spleen to be lower than usual in relation to the left lobe of the liver. The stomach has taken up free pertechnetate present in the sulfur colloid.

abdominal wall; a concave rather than convex lateral border of the liver; and close contact between the tip of the right lobe and the abdominal wall. Ascites can also produce a gap between the liver and the diaphragm but the convex lateral border of the liver is maintained and the tip of the right lobe is particularly displaced. Scintiphotos with the patient erect also assist in differentiating a local lesion from free fluid.

A male patient (E. L.) who had a fluid-filled giant bulla in the posterior segment of the right lower lobe and bullae elsewhere in the lungs (Fig. 8), demonstrates the additional information obtained by combining transmission studies with pulmonary perfusion emission studies in the evaluation of pulmonary pathology. There was good correspondence between the emission and transmission pictures of the right lung except for a small area at the costophrenic angle. At the left base the transmission pictures representing air-filled lung tissue [Fig. 9(A)] did not match the emission pictures (B) representing blood flow. Bullae are present in the left lower lobe in the chest x-ray (Fig. 8). Scintiphotos demonstrating regional expansion of the lung in the vicinity of the fluid-filled bulla are included in the composite illustration (C) and (D) as well as emission and transmission photographs taken during breath-holding in deep inspiration (E) and (F).

Finally, in Fig. 10 two methods of locating the stomach during scintillation camera studies are illustrated. A transmission picture of the right upper abdomen (A) is shown for comparison with (B), an identical view in which the stomach is now outlined by gas after 200 ml carbonated beverage. The liver is seen between the lung above and the stomach below. A view of the left hypochondrium with barium in the fundus and body of the stomach as the subject lies supine is shown in (C).

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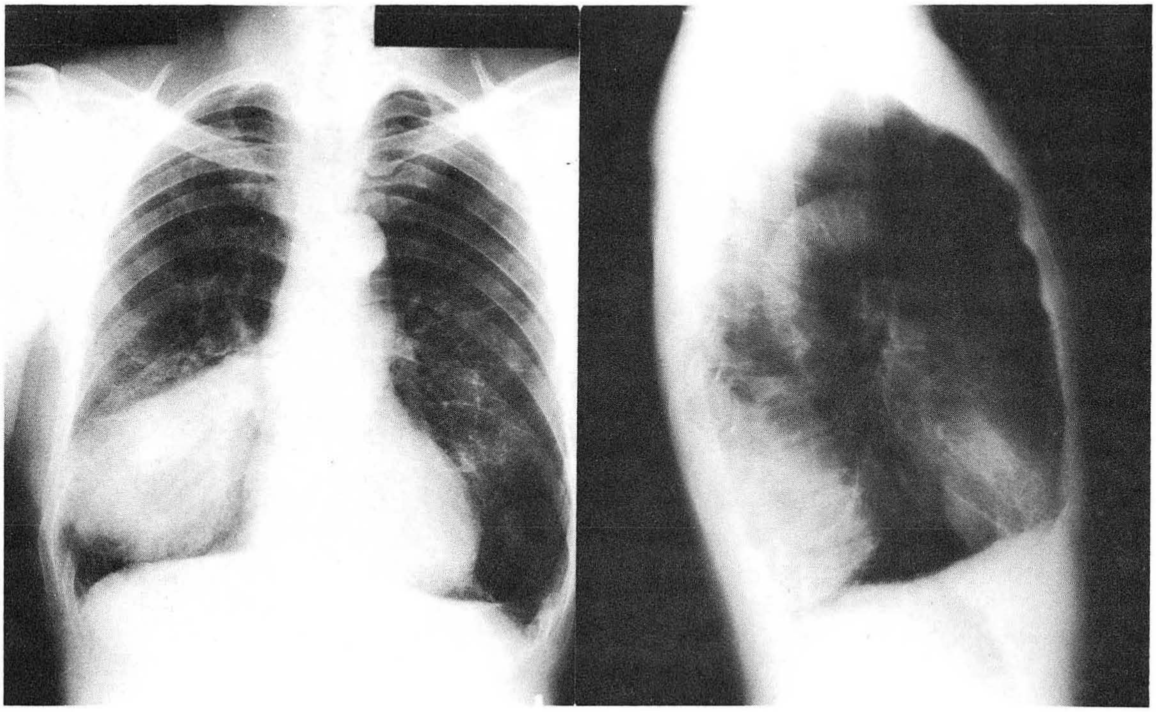

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Fig. 8. PA and lateral chest x-rays showing diffuse emphysema with a giant fluid-filled bulla in the posterior segment of the right lower lobe and big bullae elsewhere in both lungs, particularly at the left base.

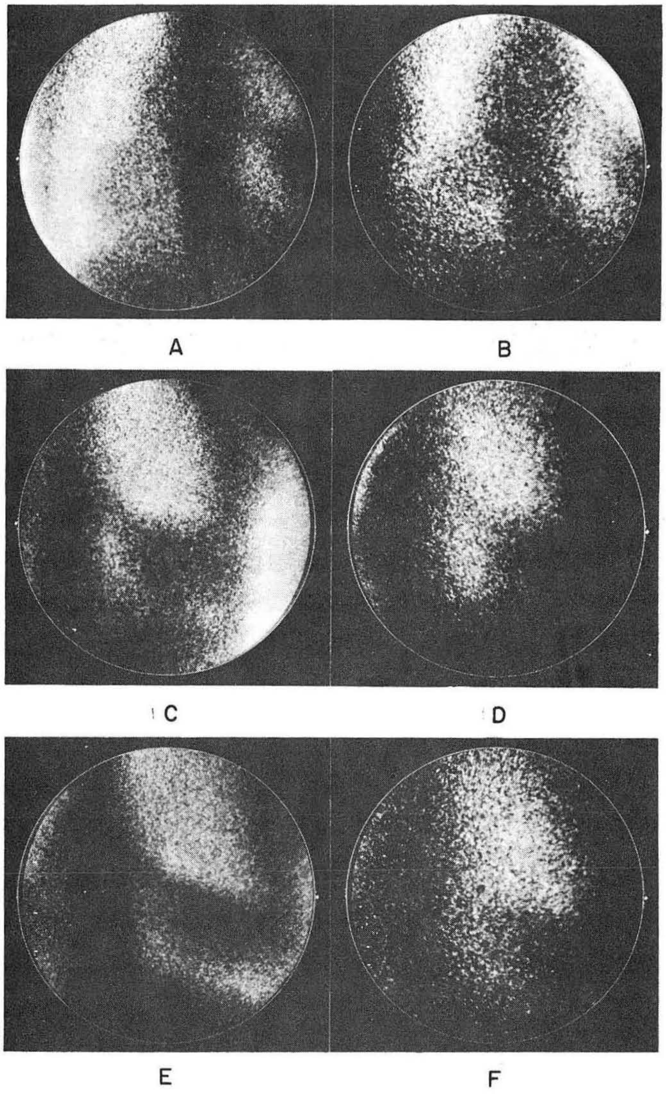

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Fig. 9. ^{99m}Tc disc source transmission scintiphotos and corresponding ^{131}I MAA emission pictures of the patient (B. P.) whose x-rays are shown in Fig. 8.

A. AP transmission view of the left lung base showing maximum transmission at the costophrenic angle.

B. Corresponding posterior scintiphoto shows little isotope in the costophrenic angle and behind the heart.

C. AP transmission view of the right lung which shows the fluid-filled bulla.

D. Corresponding posterior emission scintiphoto with similar pattern except at the apex of the costophrenic angle.

E. AP transmission view of the right lung during breath-holding in deep inspiration. The lung around the bulla has expanded.

F. Corresponding emission scintiphoto with breath-holding. The position of the patient was different for C, D and E, F.

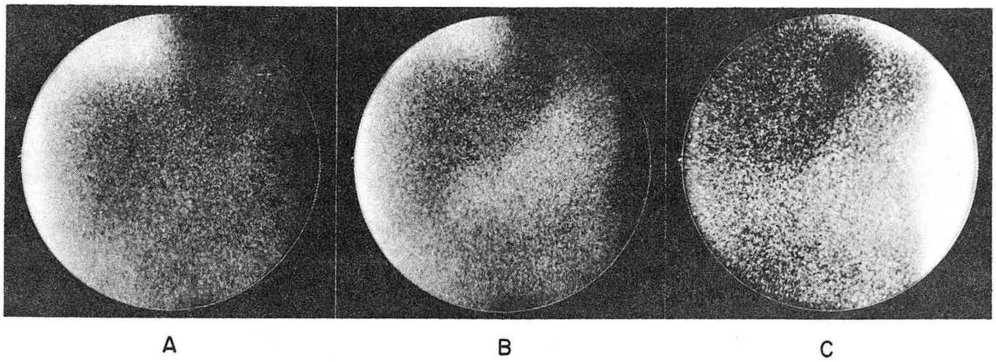

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Fig. 10. Disc transmission scintiphotos of the right upper abdomen before (A) and after drinking 200 ml carbonated beverage (B). The stomach is outlined with gas in (B) and the liver is visible between stomach and lung. Barium is shown in the fundus and body of the stomach in a scintiphoto of the right hypochondrium(C).