LUNG UPTAKE OF ^{99m}Tc-SULFUR COLLOID

William C. Klingensmith III and Thomas W. Ryerson

University of Colorado Medical Center and Veterans Administration Hospital, Denver, Colorado

Increased lung uptake of ^{99m}Tc-sulfur colloid on repeated studies is reported in a patient with a spleen and bone marrow transplant and in a patient with a malignant lymphoma. Neither patient had increased bone marrow uptake. Heart and lung time-activity curves were used to study the mechanism of increased lung uptake. The curves suggest a reticuloendothelial mechanism rather than embolization of macroaggregates.

Normally, only a very small amount of ^{99m}Tc-sulfur colloid is taken up by the lungs (*1*). However, significant lung uptake of this material has previously been reported from this institution in patients with liver transplants (*2–4*). Recently, we have noted increased lung uptake of ^{99m}Tc-sulfur colloid on repeated studies in a patient with a spleen and bone marrow transplant and in a patient with a malignant lymphoma. Although some investigators have attributed occasional "hot lungs" on liver scans to pulmonary embolization of macroaggregates secondary to technical factors (*5–7*), this seemed an unlikely cause in our cases because the lung uptake occurred during repeated studies, and other patients injected with the same preparation of colloid did not show the phenomenon. Data from heart and lung time-activity curves in these two new patients suggest that the increased lung uptake of ^{99m}Tc-sulfur colloid is secondary to increased pulmonary reticuloendothelial activity.

MATERIALS AND METHODS

The ^{99m}Tc-sulfur colloid was prepared by the method of Patton, et al (*8*), and 1.5 mCi was injected for each study.

An anterior scintigram of the chest and a dynamic study were added to the conventional liver-spleen reticuloendothelial examination. The anterior chest scintigram was evaluated in each case for the presence of lung uptake and increased bone marrow uptake. Initially, after bolus injection of ^{99m}Tc-sulfur colloid, there is more activity over the heart than over the lungs because of the larger cardiac blood pool. If the activities of the two organs reflect only their blood pools, then their activities should decrease with time at the same rate and maintain a constant ratio between them. Therefore, when the anterior chest scintigram shows more activity over the lungs than over the heart, a reversal of the initial situation will have occurred indicating lung uptake. Anterior, posterior, and lateral scintigrams were used to evaluate bone marrow uptake. If a subject shows increased bone marrow uptake, a lung time-activity curve could not be constructed because of the superimposition of ribs and lung. Figure 1 shows the contrasting appearance of lung uptake as compared with increased bone marrow uptake on anterior scintigrams of two patients with liver transplants. These patients did not have dynamic studies.

The dynamic study was done with the patient in

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For reprints contact: William C. Klingensmith III, USAF Medical Center, Box 1000, Scott AFB, Ill. 62225.

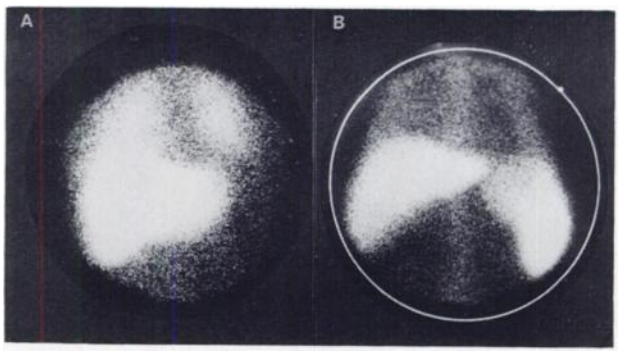

FIG. 1. Anterior chest scintigrams of ^{99m}Tc-sulfur colloid examinations in two patients with liver transplants showing different appearance of lung uptake (A) as compared to increased bone marrow uptake (B).

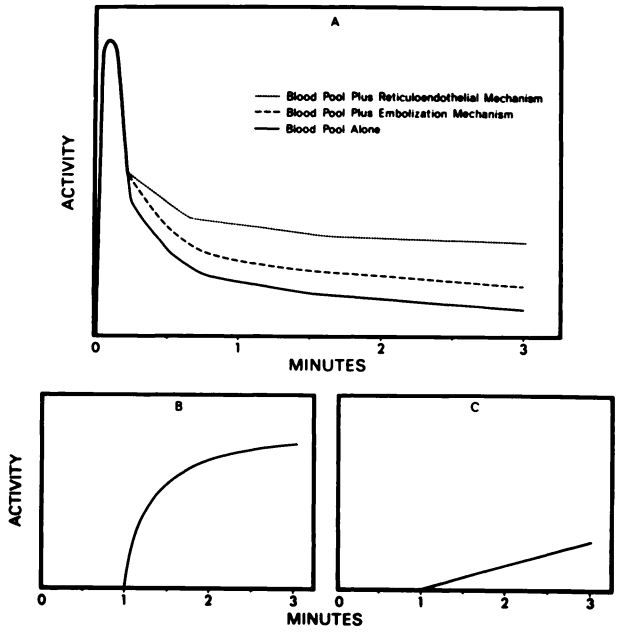

FIG. 2. A shows theoretical lung time-activity curves for blood-pool activity alone and in combination with either reticuloendothelial or embolization mechanism. B and C show nonblood-pool lung activity after subtraction of blood pool activity for reticuloendothelial and embolization mechanisms, respectively. Combined curve and blood pool curve were normalized at 1 min before subtraction.

the supine position under the crystal of a Nuclear-Chicago Pho/Gamma HP camera so that the field included the lower half of the right lung, the heart, and upper half of the liver. From each dynamic study, time-activity curves were constructed for the heart, lung, and liver using the *areas of interest* capability of the Nuclear-Chicago Data-Store/Playback Accessory and strip-chart recorders. The areas of interest were 1-cm^2 blocks positioned over the left ventricle, the lower midright lung field, and the middle of the right lobe of the liver. Care was taken to have areas of interest for the lung, with its relatively low counting rate, not overlap either the heart or the liver.

A time-activity curve for nonblood-pool lung activity can be derived from the heart and lung time-activity curves if two assumptions are made: (A) the heart time-activity curve represents cardiac blood-pool activity only; and (B) the time-activity curves for heart and lung blood pools are qualitatively similar. Figure 2 shows the theoretical lung time-activity curves for lung blood pool alone, lung blood pool plus initial embolization of some colloid, and lung blood pool plus reticuloendothelial extraction. The blood pool plus the embolization curve remains above the curve for blood pool alone by a constant amount after passage of the initial bolus. The blood pool plus the reticuloendothelial extraction curve increases its distance above the blood-pool curve with time. The nonblood-pool lung time-activity curve is obtained by subtracting the heart time-activity curve from the lung time-activity curve after normalization at 1 min. The two curves are normalized at 1 min to allow mixing of the colloid bolus so that the colloidal concentration in the blood of the heart and lung will be essentially the same at a given time. Subtraction of the curve for blood pool alone from the blood pool plus reticuloendothelial extraction curve gives a curve typical of reticuloendothelial extraction. In contrast, subtraction of the curve for blood pool alone from the blood pool plus embolization curve gives an essentially straight sloping line. The slope of the line is not zero because after normalization the two curves have different scales along the ordinate.

RESULTS

The patient with a spleen and bone marrow transplant and the patient with a malignant lymphoma had scintigrams showing lung uptake without evidence of bone marrow uptake. The former patient had a hepatoma with a metastasis to the third lumbar vertebrae and the spleen and bone marrow transplant was part of an attempt to achieve rejection of the hepatoma. This patient showed lung uptake on six consecutive scans from the 25th to the 84th day post-transplantation at which time he expired. The pre- and post-transplantation scans and post-transplantation time-activity curves for this patient are shown in Fig. 3. In this case the lung time-activity curve shows increasing activity with time even before subtraction of blood-pool activity. This result indicates that the lung is extracting colloid from its blood pool faster than the blood-pool colloid concentration is decreasing.

Figure 4 shows the anterior chest scintigram and the subtracted curve of nonblood pool lung activity in the patient with biopsy-proven malignant lymphoma*. The scintigram shows lung uptake and the nonblood-pool lung activity curve is typical of reticuloendothelial extraction.

Liver time-activity curves were constructed in both of these patients and were felt to be normal and noncontributory.

DISCUSSION

Intravenously injected colloids are extracted by those reticuloendothelial cells which line capillary walls. These cells are found predominantly in the liver, spleen, and bone marrow (*9*). The distribu-

* We are indebted to Duncan Burdick, Denver General Hospital, for the scintigrams and time-activity curves on this patient.

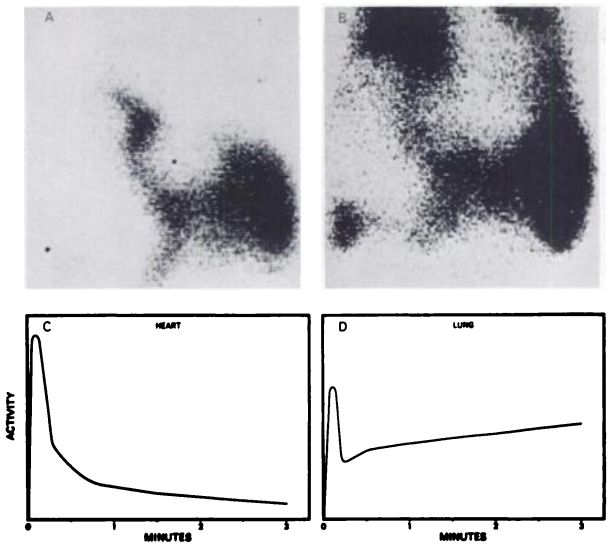

FIG. 3. A is pretransplantation anterior liver scan showing large hepatoma and clear lung fields (upper portion of scan). B, C, and D are anterior liver scan and corresponding time-activity curves 84 days postspleen and bone marrow transplant. Scan shows marked lung uptake. Heart time-activity curve is normal but lung time-activity curve is unusual because it shows increasing activity with time even before subtracting blood pool activity.

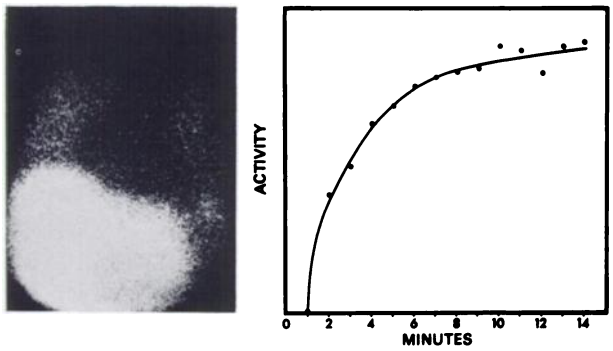

FIG. 4. Anterior chest scintigram of a patient with a malignant lymphoma showing lung uptake of ^{99m}Tc-sulfur colloid. Subtracted curve representing nonblood pool lung activity is suggestive of reticuloendothelial mechanism. Heart and lung time-activity curves were normalized at 1 min before subtraction.

tion of colloid among these organs depends on many factors including blood flow, competing substances, immunologic competence, and particle characteristics such as size, charge, and chemical composition (*10*). Normally, in the case of ^{99m}Tc-sulfur colloid, approximately 80% is extracted by the liver, 15% by the spleen, and 5% by the bone marrow (*1*). Lung uptake of this colloid has been observed in patients with liver transplants (*2–4*), and we are reporting lung uptake in one patient with a spleen and bone marrow transplant and in another patient with a malignant lymphoma. Although the former patient definitely had liver damage and the latter also may have had liver damage, simple compensatory uptake by the lung seems unlikely because the bone marrow would be expected to take up more colloid than the lung as in cirrhosis (*11*).

The most likely mechanism for lung uptake of ^{99m}Tc-sulfur colloid would seem to be either reticuloendothelial extraction or embolization of macroaggregates. The subtracted nonblood-pool lung activity curve for the patient with the malignant lymphoma is characteristic of reticuloendothelial extraction (Fig. 4). Also, only the reticuloendothelial mechanism should result in increasing activity with time before blood-pool subtraction as seen in the patient with the spleen and bone marrow transplant (Fig. 3). It would be possible for macroaggregation to mimic the reticuloendothelial mechanism if the macroaggregation continued over time. However, since macroaggregation would be expected to occur in both venous and arterial systems, other organs with large blood flows such as the kidneys should also trap detectable amounts of ^{99m}Tc-sulfur colloid. This phenomenon was not observed.

In 1922, Simpson (*12*) showed macrophages in rabbits tend to migrate from the spleen and liver to the lungs. He also showed that with chronic intravenous colloidal stimulation, showers of macrophages would periodically embolize to the lungs. In 1932, Erwin (*13*) and later others (*14–16*) showed these macrophages in animals eventually appear in the bronchial tree after migrating from the spleen and liver to the lung. In 1970, Schneeberger-Keeley and Burger (*17*) showed in cats that the stress of open chest ventilation for 1 hr causes large numbers of Kupffer cells to migrate to the lung capillaries. In addition, they showed that the Kupffer cells actively continue to phagocytize intravascular colloid after their migration. The intravascular reticuloendothelial cells, which we postulate for human lungs in this study, may have a source similar to the one shown for animals.

ACKNOWLEDGMENTS

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