Annals of Nuclear Medicine Vol. 14, No. 3, 217–221, 2000

Transient right-to-left shunt in massive pulmonary embolism

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A 56-yr-old man, two months after an operation for an acoustic neurinoma, gradually developed dyspnea. Massive pulmonary embolism (MPE), with a significant right-to-left (R-L) shunt, was seen in a perfusion scan of the lungs with Tc-99m MAA. Radioactivity was noted in the thyroid, spleen, kidneys and brain. A cardiac ultrasound study did not reveal intracardiac shunting. A few days later, when the patient's condition improved, another perfusion scan of the lungs did not show the shunt, whereas a subsequent digital subtraction angiographic study confirmed the diagnosis of MPE but failed to reveal the cause of the shunt. In the absence of any possible pathophysiological mechanism, to explain the observed R-L shunt, we deduce that the particles of Tc-99m MAA might have passed through the precapillary pulmonary arteriovenous anastomoses and/or through dilated pulmonary capillaries, as a result of highly increased pulmonary vascular pressure due to MPE.

Key words: transient right-to-left shunt, pulmonary embolism, perfusion scan

INTRODUCTION

SEVERAL PATHOLOGIC ENTITIES can give rise to a right-to-left (R-L) shunt, most notably through a persistent sinus duct, an atrial or ventricular septal defect or an extracardiac arteriovenous communication.[1–9] We recently studied a patient, who was suffering from massive pulmonary embolism (MPE), in whom a significant, but transient R-L shunt was evident, but this shunt could not be clearly attributed to known causes.

CASE REPORT

A 56-yr-old non smoker was referred to our department immediately after his admission for evaluation of severe dyspnoea and moderate cyanosis. Two months earlier he had been successfully operated on for a left acoustic nerve neurinoma. Fifty days after the operation mild dyspnea appeared, which gradually worsened and after ten days necessitated hospitalization. Upon admission he did not complain of pain, cough or hemoptysis. The past history was unremarkable and free of disease. Physical examination disclosed tachypnea, with a respiratory rate of 40 breaths/min, tachycardia, with a pulse rate of 140 beats/min and moderate central and peripheral cyanosis. Blood pressure was 140/80 mmHg. There was no evidence of clubbing. The cardiopulmonary auscultation was normal (no murmurs). Arterial blood gases, on 50% O_2 Venturi mask, were PaO_2: 33 mmHg, $PaCO_2$: 35 mmHg and pH: 7.47. The chest x-ray was unremarkable. Hematocrit was at 44.8%, hemoglobin was 14.2 g/100 mL and the total WBC count was 10,100/mm^3 (with 0.1% eosinophils). A perfusion scan was performed after injecting, in a supine position, 111 MBq of Tc-99m macroaggregated human serum albumin (Tc-99m MAA) into a left arm vein. The images showed a very unusual pattern: radioactivity was poor in the lungs, especially in the upper pulmonary fields (Fig. 1A), but most of the radioactivity was seen in the systemic circulation (brain, kidneys, thyroid, spleen, myocardium and liver) (Fig. 1A, B, C). Consequently it was difficult to distinguish the lungs from the liver, the spleen and the myocardium. This pattern raised the suspicion of an intracardiac R-L shunt, of a pulmonary arteriovenous fistula, or of shunting via anomalous systemic venous communication with the left heart, such as a through the left superior vena cava. Immediately, a second smaller dose of 37 MBq of Tc-99m MAA was administered via the right antecubital vein, but the pattern did not change. The apparent diagnosis was of that of

Received January 13, 2000, revision accepted March 13, 2000.

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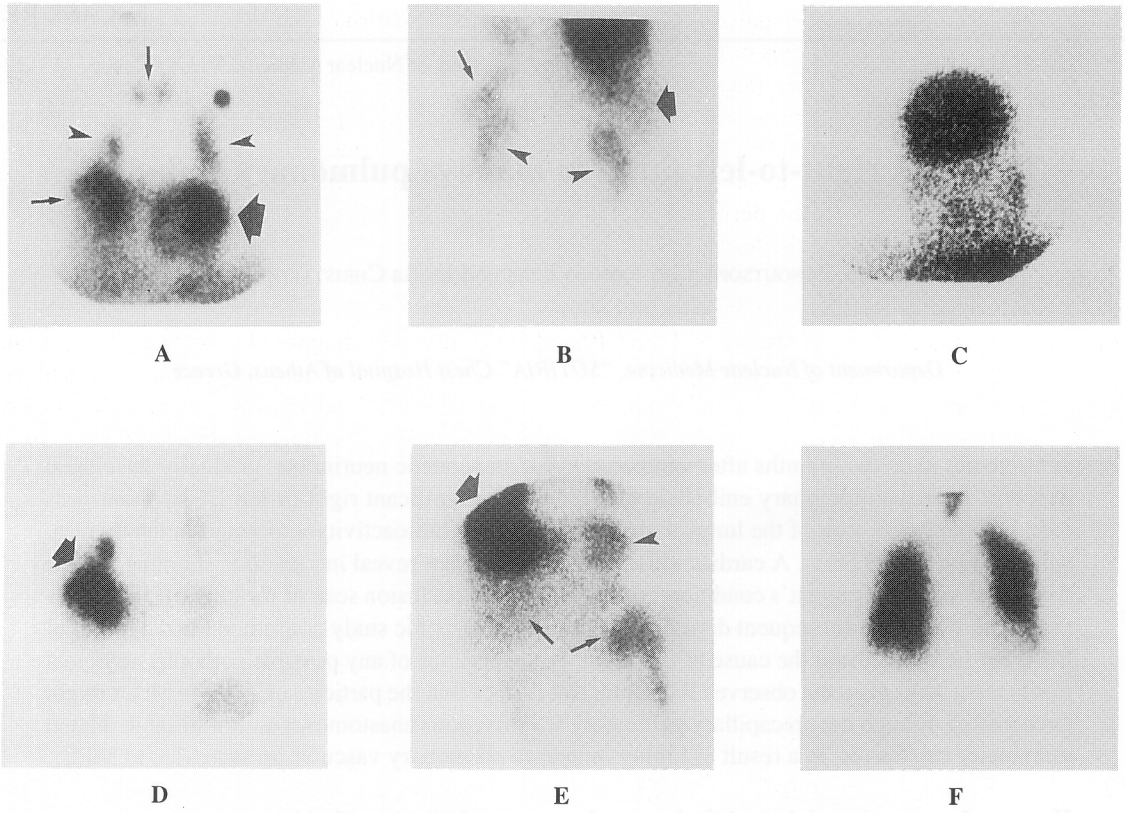


Fig. 1 A–C: Initial Tc-99m MAA perfusion images after a left antecubital iv injection (day 1). A: Thorax and upper abdomen (anterior view). Poor activity in the upper pulmonary regions (arrowheads), increased activity in the cardiac region (thick arrow), the right lower pulmonary field and the thyroid (smaller arrows). B: Lower thoracic and lumbar region (posterior view). Increased activity in the kidneys (arrowheads), liver (thick arrow) and the spleen (small arrow). C: Head and neck region (anterior view). Increased activity in the brain.
D–E: Tc-99m MAA perfusion images after injection via a leg vein (anterior views, day 2).
D: Increased activity of the lower right pulmonary area (large arrow). E: This image is more intense than Fig. 1D, though both were obtained at the same time, in order to render it comparable to Fig. 1A. Increased activity is observed in the right lower pulmonary area (large arrow), myocardium (arrowhead) and the liver (small arrow). The spleen's activity (small arrow) is more intense compared to Fig. 1B. Normally the spleen is more clearly visible in posterior views, note, however, that the overall images' intensities are different and that they were obtained on different days depicting differing instances of a dynamic phenomenon. F: Ventilation scan with Tc-99m DTPA-aerosol (anterior view, day 2) is within normal limits.

MPE and heparin infusion was started in order to protect from further pulmonary emboli. Echocardiography (two-dimensional, Doppler color flow mapping) revealed dilation of the right ventricle and atrium, in contrast to the left chambers which had normal dimensions. The same method revealed tricuspid valve regurgitation and abnormal motion of the septum, but did not reveal intracardiac R-L shunt. The right ventricular blood pressure, with Doppler measurements, was estimated at approximately 70 mmHg. Although the patient was in a state of respiratory failure, his condition did not deteriorate and intubation was delayed until further diagnostic work-up was carried out. On the following day, a second perfusion scan via a leg vein showed substantially the same pattern (Fig. 1D, E). The only difference was a slight improvement in perfusion in the lower lobe of the right lung and further deterioration of the perfusion in the left lung. A significant R-L shunt was still present. After a normal ventilation scan (Fig. 1F) the diagnosis of a MPE with a R-L shunt was sustained. The next day, in an effort to localize and confirm the R-L shunt, first-pass radionuclide angiocardiography was performed with a bolus of 555 MBq of Tc-99m DTPA, injected via the right antecubital vein (Fig. 2). The dynamic images showed the progression of the radiotracer through the right subclavian vein, the superior vena cava, the right atrium, the right ventricle and the trunk of the pulmonary artery. The left pulmonary artery, the left lung and the upper field of the right lung were not delineated. Moreover, faint imaging of the right internal jugular vein and of the left subclavian vein was noted. The aorta

appeared faintly, 11 seconds after visualization of the right ventricle. No shunting via anomalous systemic venous communication with the left heart or an intracardiac R-L shunt was revealed. A repeat perfusion scan 2 days later when the patient was in better condition (PaO_2: 73 mmHg, $PaCO_2$: 30 mmHg and pH 7.46—on a Venturi mask of 50% O_2) showed improvement in the perfusion of the right lung, but lack of perfusion of the left lung and no appearance of the radiopharmaceutical in the systemic circulation (Fig. 3). Digital subtraction angiography (DSA) was performed 3 days later. Total obstruction of the left pulmonary artery by thrombi and of the middle branch of the right pulmonary artery were evident, so that although MPE was confirmed, no R-L shunting was seen (Fig. 4). A new perfusion scan 2 months after the first one (with the patient's arterial blood gases at PaO_2: 78 mmHg and $PaCO_2$: 33 mmHg—breathing room air) showed further improvement in the perfusion of the right lung and a slight improvement in the left lung without systemic activity (Fig. 5).

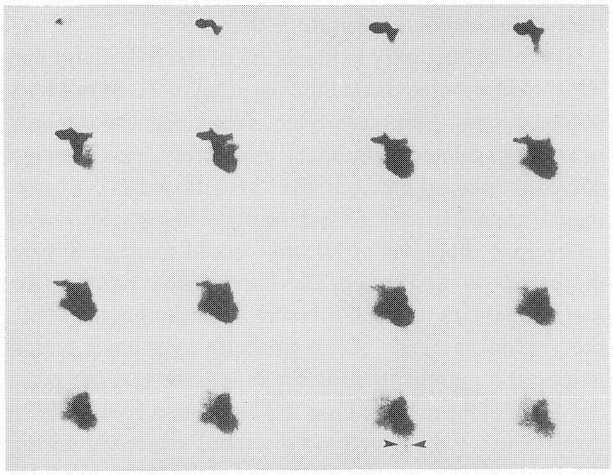
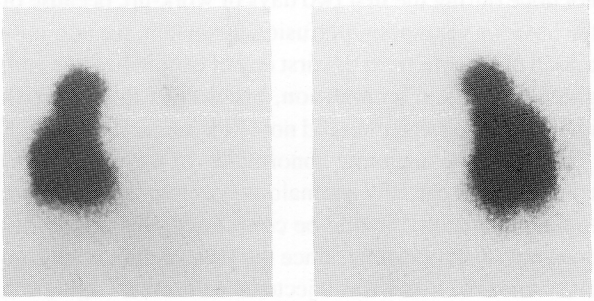


Fig. 2 First pass radionuclide angiocardiogram (anterior view, day 3) obtained after a right arm vein injection of 555 MBq of Tc-99m DTPA. Frame duration is 1.0 sec. The radiotracer passes through the right subclavian vein, the superior vena cava, the right atrium and ventricle and the main pulmonary artery. Faint visualisation of the aorta (arrowheads) 11 sec. after the visualisation of the right ventricle. There is no appearance of either the left pulmonary artery and the left lung, or the upper field of the right lung. No evidence of R-L shunting.

DISCUSSION

Our patient was diagnosed as having a MPE. Pulmonary embolism occurs more commonly in vessels of the lower lung segments[10] and, consequently, administration of Tc-99m MAA results in increased radionuclide accumulation in the upper pulmonary fields. This scintigraphic finding is facilitated by the increased pulmonary vascular pressures and the administration of Tc-99m MAA in the supine position. In the case presented, pulmonary embolism was the result of a large thrombus, which initially prevented the passage of Tc-99m MAA mainly to the upper lung segments. Moreover, a significant transient R-L shunt was revealed by the appearance of radioactivity in



A B

Fig. 3 Repeated perfusion scan with Tc-99m MAA via a left arm vein (day 5). A: Anterior view, B: Posterior view. Improvement in the perfusion of the right lung, lack of perfusion of the left lung, no evidence of R-L shunting.

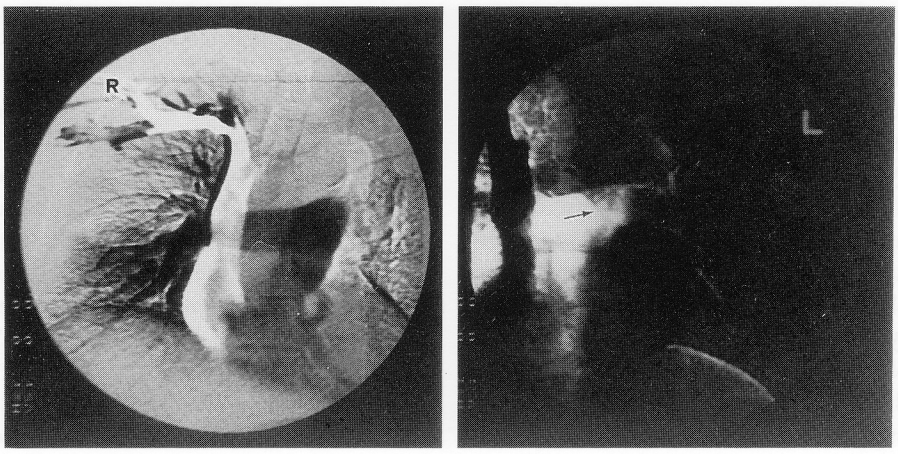
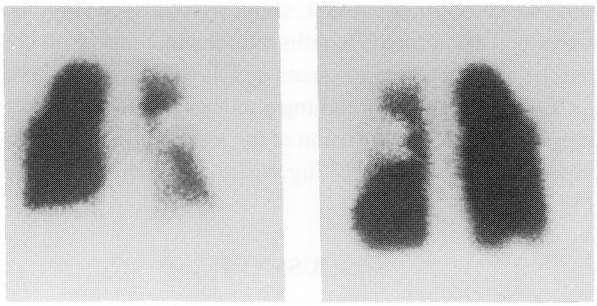


Fig. 4 Digital subtraction angiography (day 8). Obstruction of the left pulmonary artery by a thrombus (arrow).



A B

Fig. 5 Perfusion scan 2 months later. A: Anterior view, B: Posterior view. Significant improvement of the perfusion of both lungs. No evidence of R-L shunting.

the systemic circulation. Tc-99m MAA particles are trapped in the capillaries of organs in the systemic circulation. Organs with dense capillary networks and significant blood flow (such as the brain, the kidneys, the thyroid, the spleen and the myocardium) are visualized more intensely. Right cardiac catheterization—in order to clarify the diagnosis of MPE and to localize the R-L shunt—was not done during the first two days of work-up, because of the obvious ventilation/perfusion mismatch, the administration of heparin from the first day of hospitalization and, given the patient's condition, because of the high risk involved. The same risks did not allow surgical treatment.

Although an anatomic abnormality of the venous system, such as a partially anomalous systemic venous return to the left atrium[1–3] could be considered, this possibility does not seem plausible, since the pattern did not change even when the tracer was injected via the other (right) arm or leg. Moreover, abnormalities in imaging should have been constant and not transient. The presence of an atrial (e.g. foramen ovale) or ventricular septal defect combined with high pulmonary vascular pressure—as a result of the MPE[4,7–9]—could be considered, since in such a case a R-L shunt could be favored. This condition could also explain the disappearance of radioactivity from the systemic circulation after improvement of the pulmonary circulation and decrease in pulmonary pressure. But this possibility also seems unlikely, since it is not corroborated by prior medical history, clinical examination (no murmurs), radionuclide first-pass angiocardiography, and echocardiography. The latter should have shown dilation of the left atrium, which it did not in our case. In an analogous way, a R-L shunt via a patent ductus arteriosus was also ruled out. Pulmonary arteriovenous fistula was ruled out by the chest x-ray and DSA.[5] The appearance of the tracer in the systemic circulation could be the result of a great amount of free radioactivity in the injected solution or the small size of the injected particles. Both of these possibilities were excluded: the injected dose was taken from a newly prepared and carefully controlled solution with radiochemical purity of the Tc-99m MAA more than 99%. Moreover, if the particles were too small they would mainly be localized in the liver by phagocytosis and would not be trapped in the capillaries of organs with high systemic blood flow, such as the thyroid or the kidneys. Furthermore, angiolymphoid hyperplasia with eosinophilia (Kimura's disease) was ruled out.[6]

It is known that at high pulmonary vascular pressures, distension of capillaries occurs.[11,12] This increase in the caliber of pulmonary capillaries is the result of the altered relationship between the alveolar pressure and the capillary pressure and made possible by the thinness of the membrane which separates the capillaries from the alveolar space.[12] Apart from distension—as the predominant compensating mechanism—high pulmonary vascular pressures are also countered with capillary recruitment (intrapulmonary compensatory shunt).[12]

Therefore, the only explanation of the R-L shunt that we could formulate is that the particles of Tc-99m MAA passed through pulmonary arteriovenus anastomoses and/or through dilated pulmonary capillaries. This passage could take place if the capillaries were dilated to 2–4 times their normal diameter, so that the injected particles—with an average diameter of 30 μm—could manage to pass through the dilated lumen. This hypothesis is based on the high pulmonary vascular pressure, as a result of the MPE, the gradual increase in this pressure over days, which helped the patient to adjust/compensate and the good condition of the myocardium and lung parenchyma. These three factors contributed to the patient's survival during the acute phase, during which the pulmonary vascular pressure reached a high level.

Pulmonary capillary distension could explain the lack of the "hyperperfusion sign" in the first and second perfusion scans,[13] as the Tc-99m MAA particles were not trapped in the lungs. In contrast, the subsequent decrease in pulmonary vascular pressure and caliber could explain the disappearance of the systemic activity as well as the hyperperfusion of pulmonary segments in the third perfusion scan, when trapping of Tc-99m MAA particles in the lungs became possible. It is remarkable that even at the time the third perfusion scan was done—and no shunt was evident—most of the pulmonary network remained obstructed.

To the best of our knowledge, there have been no analogous reports of such transient R-L shunts, without evidence of congenital/anatomic or other known abnormalites, in the literature. This could be due to the patients' demise before evaluation or due to the acquiring of perfusion images after the disappearance of the compensatory shunt. We therefore hypothesize that, in cases of gradual onset MPE, beyond a "critical" level of pulmonary vascular network obstruction—in individuals with no cardiac or lung diseases—a transient R-L shunt could be noticed in the absence of relevant congenital abnormalities.

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