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SELF-STUDY TEST

Pulmonary Nuclear Medicine

Questions are taken from the *Nuclear Medicine Self-Study Program 1,* published by The Society of Nuclear Medicine

DIRECTIONS

The following items consist of a heading followed by lettered options related to that heading. Select the one lettered option that is best for each item. Answers may be found on page 233.

For each scintigraphic pattern (items 1-5), select the most appropriate interpretation (answers A-E)

A. normal
B. low probability of pulmonary embolism
C. intermediate probability of pulmonary embolism
D. high probability of pulmonary embolism
E. additional information is necessary before interpretation

1. There are multiple, large, matching ventilation-perfusion abnormalities involving about 75% of the total lung volume. The chest radiograph shows no infiltrates, effusions, or atelectasis.

2. Perfusion is absent in the entire posterior basal segment of the left lower lobe. The chest radiograph and ventilation study are normal.

3. Perfusion defects involve all of the posterior basal segment and the superior segment of the right lower lobe. The chest radiograph shows only a very small infiltrate in the superior segment of the right lower lobe and the ventilation study is normal.

4. There are large perfusion defects in the superior segment and posterior basal segment of the right lower lobe. The ventilation study shows subtle washin abnormalities in these regions, but the washout phase is normal. A portable chest radiograph obtained 18 hours before the scintigrams shows a very small infiltrate in the superior segment of the right lower lobe.

5. There are matching ventilation and perfusion abnormalities in the anterior segment of the right upper lobe. The chest radiograph shows consolidation of the same segment

For each of the following situations (items 6-10), select the most appropriate estimate for the post-test probability of pulmonary embolism (answers A-E)

A. very high (>99%)
B. high (85%-98%)
C. moderate (16%-84%)
D. low (1%-15%)
E. very low (<1%)

6. An elderly woman experiences acute chest pain, shortness of breath, and tachypnea 3 days after undergoing surgery for a femoral neck fracture. Perfusion images show a large, wedge-shaped perfusion defect with a corresponding radiographic infiltrate.

7. A middle-aged man with mild chest pain has known coronary artery disease and classic clinical and radiographic findings of congestive heart failure. The ventilation-perfusion study is normal except for a washin ventilation defect and a perfusion defect corresponding to a large right pleural effusion.

8. Ventilation-perfusion scintigraphy is requested as part of a screening evaluation of a healthy kidney donor. The study is normal except for a single, medium-size perfusion defect.

9. A patient on hemodialysis for chronic renal failure has only minimal, vague respiratory complaints and a normal chest radiograph. A ventilation-perfusion study reveals two segmental perfusion defects and normal ventilation.

10. Four wedge-shaped, segmental, matching ventilation-perfusion defects are seen in a patient who has cancer and who has experienced the acute onset of pleuritic chest pain, dyspnea, and tachypnea 2 hours ago. The chest radiograph is normal.

For each patient profile (items 11-15), select the most closely associated functional description (answers A-E)

A. Increased alveolar compliance, increased airways resistance, regions of increased xenon clearance time.
B. Normal alveolar compliance, transiently increased airways resistance, decreased global xenon clearance time.

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SELF-STUDY TEST
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QUESTIONS *(continued)*

C. Reduced alveolar compliance, markedly reduced clearance time of ^{99m}Tc DTPA aerosol.
D. Decreased alveolar compliance, increased airways resistance, normal xenon clearance time.
E. Normal compliance, increased small airways resistance, normal or mildly heterogeneous regional xenon clearance time.

11. 28-year-old man with a 10 pack-year smoking history
12. 45-year-old woman with a 60 pack-year smoking history
13. 25-year-old man with a tibial fracture 1 week ago and acute onset of dyspnea
14. 25-year-old man with massive internal injuries resulting from a motor vehicle accident
15. 40-year-old woman with idiopathic pulmonary fibrosis

For each pattern of thoracic Ga uptake (items 16-20), select the most closely associated diagnosis (answers A-E)

A. sarcoidosis
B. *Pneumocystis carinii* pneumonia
C. primary lung cancer
D. chronic interstitial pneumonitis
E. bacterial pneumonia

16. Several small mediastinal foci and a larger, less well defined region of uptake in the right middle lobe.
17. Intense uptake limited to the right middle lobe.
18. Prominent uptake in both hilar regions and the right paramediastinal region, and diffuse bilateral lower lobe uptake.
19. Diffuse, bilateral high-intensity pulmonary uptake.
20. Irregular parenchymal uptake predominantly in the lower lung zones.

SELF-STUDY TEST
Pulmonary Nuclear Medicine

ANSWERS

Items 1-5: Ventilation-Perfusion Scintigraphic Patterns
Answers: 1, C; 2, C; 3, D; 4, E; 5, C

Ventilation-perfusion "matches" with a normal radiograph should be interpreted as indicating an intermediate probability for pulmonary embolism if the ventilation abnormalities involve more than 50% of the lung fields. When obstructive pulmonary disease is diffuse or extensive, it may not be possible to recognize coexisting ventilation-perfusion mismatching due to superimposed pulmonary embolism.

A single, unmatched perfusion defect, even if segmental in size, should be interpreted as an intermediate-probability finding. Some earlier interpretation schemes suggested that this finding indicated a high probability of pulmonary embolism; more recent studies, however, show that this scintigraphic pattern is associated with an intermediate probability.

When a perfusion defect is much larger than the associated radiographic opacity, the defect can be considered essentially as unmatched by the radiographic abnormality (assuming there is no ventilation abnormality in that part of the perfusion defect outside of the region of radiographic opacity). Thus, the finding of two segmental (large) perfusion defects with normal ventilation and only a small radiographic density associated with one of them, indicates a high probability of pulmonary embolism.

The chest radiograph should be obtained at approximately the same time as the scintigraphic study. In patients with stable clinical and radiographic findings, this interval could be as long as 18-24 hours. When the patient's clinical condition is changing or there are newly evolved radiographic abnormalities on prior films, the chest radiograph for comparison with the scintigrams should be obtained much closer in time to the ventilationperfusion study. In the situation described in Item 4 the infiltrate could have enlarged during the 18-hour interval to more closely match the perfusion abnormality in the superior segment. Additionally, new infiltrate may have developed in the posterior basal segment. The subtle washin abnormalities noted on the ventilation study suggest that

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SELF-STUDY TEST
Pulmonary Nuclear Medicine

ANSWERS

these changes, indeed, may have occurred. The examination should be considered nondiagnostic up to this point. A new chest radiographic examination should be obtained (ideally, standard erect posteroanterior and lateral films). If matching infiltrates have developed, the findings would indicate an intermediate probabilty of pulmonary embolism; if not, a high probability interpretation would be appropriate. As a corollary, it should be noted that an increasing period of time between onset of symptoms and ventilation perfusion imaging is associated with an increasing likelihood that an intermediate-probability interpretation will result, in part reflecting the evolution of new radiographic abnormalities in patients with pulmonary embolism.

The use of the term "ventilationperfusion match" can be misleading. A ventilation-perfusion match only represents a low probability for pulmonary embolism when the chest radiograph is normal. A radiographic opacity correlating with a perfusion defect takes precedence over a ventilation perfusion match, and should lead to an intermediate-probability interpretation.

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Items 6-10: Assessing the Post-Test Probability of Pulmonary Embolism

Answers: 6, C; 7, D; 8, D; 9, C; 10, C

The principles of Bayes' theorem can be used to answer these questions, which require that one consider both the scintigraphic findings and the clinical data for each patient. Although ventilation-perfusion scintigrams usually are interpreted with reference to the likelihood or probability of pulmonary embolism corresponding to a particular set of findings on the images, the actual post-test probability of embolism in any patient depends on both the scintigraphic result and the pretest probability of pulmonary embolism based on the constellation of risk factors, symptoms, physical signs, laboratory data, and radiographic findings in a particular patient. Admittedly, this probability is difficult to determine precisely, but experienced clinicians can estimate the likelihood of embolism as low, moderate, or high with reasonable accuracy by carefully evaluating all of the patient's clinical information. The first patient has intermediate probability scintigraphic findings, but a very high clinical probability for pulmonary embolism. Thus, she has a moderately high post-test probability of embolism. Some clinicians might consider anticoagulation at this point, but most others would proceed with further diagnostic studies in this clinical setting.

The history and radiographic findings in the second patient are most suggestive of heart disease with congestive failure, not pulmonary embolism. Thus, the post-test probability of embolism is low, and in this setting, many physicians would not search further for pulmonary embolism despite the intermediate-probability scintigraphic result. Additionally, one recent study has suggested that a perfusion defect corresponding to a pleural effusion is unlikely to represent pulmonary embolism. However, there is not general agreement on this point, and most diagnostic schemes still classify such findings as indicative of an intermediate likelihood for pulmonary embolism on scintigraphic grounds alone.

There is no reason for the third patient to have acute pulmonary embolism. This single perfusion defect, leading to an intermediate-probability scintigraphic interpretation, is likely due to one of the other causes discussed in the syllabus text.

The fourth patient, who is on chronic hemodialysis, has a high-probability scintigraphic result. Because pulmonary embolism is relatively uncommon in patients on hemodialysis, presumably because they receive heparin during dialysis and because of the hemostatic defect associated with renal insufficiency, the pre-test likelihood of embolism is low, leading to only a moderate post-test probability of embolism. Thus, it would seem prudent to do further testing, such as pulmonary angiography or a search for lower-extremity deep venous thrombosis, in this patient.

The last patient has a very suggestive history for pulmonary embolism but an apparently low-probability scintigraphic study. Thus, the post-test probability of embolism is moderate. In fact, there is an additional clue that pulmonary emboli may be present: the defects are wedge-shaped and segmental and the symptoms began a very short time before the lung scan. Infrequently, pulmonary emboli may lead to reflex bronchoconstriction during the first few hours after the embolic event. This bronchoconstriction is likely due to local hypocapnia and the release of serotonin and other substances from platelets at the site of the embolus. The associated abnormality on ventilation imaging will closely match the perfusion defect and will generally resolve within approximately 6 hours of the time of embolization. Recognition of this phenomenon can be very difficult because ventilation perfusion matches with a normal radiograph generally are interpreted as indicating a low-probability for pulmonary embolism. The principal features of this case suggesting pulmonary embolism with bronchospasm are

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ANSWERS

the worrisome history, the characteristics of the perfusion defects, and the short interval since onset of symptoms. If pulmonary angiography is not performed, the possibility of embolism with reflex bronchoconstriction can be assessed further with repeat ventilation perfusionimaging 18-24 hours later, when ventilation likely would have returned to normal in a patient with embolism.

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Items 11-15: Patterns of Altered Function in Pulmonary Disease

Answers: 11, E; 12, A; 13, B; 14 C; 15, D

Histopathologic studies of the lungs of young smokers demonstrate definite pathologic changes in the peripheral airways. The characteristic lesion is a respiratory bronchiolitis consisting of clusters of brown pigmented macrophages often accompanied by edema, fibrosis, and epithelial hyperplasia in the adjacent bronchiolar and alveolar walls. These abnormalities can be detected in some smokers by measurements of dynamic compliance, closing volumes, and flow-volume loops; however, the changes generally are too subtle to be detected by standard pulmonary function studies. Xenon washout studies have shown mild delay in regional clearance and heterogeneity of clearance time constants in the lungs of young smokers. In long-term smokers, these changes become progressively more severe and irreversible as proteases in the lysosomes of invading macrophages cause enzymatic destruction of the elastin and collagen fibers of alveolar walls. Loss of alveolar integrity resulting from this process increases alveolar volume and regional compliance and decreases the lung's elastic recoil, which is partially responsible for maintaining airway patency. Goblet cell hyperplasia in response to airway irritants in smoke results in increased mucous secretion and further compromise of the airway lumen. The regional xenon clearance time increases as both alveolar compliance and airway resistance increase.

The 25-year-old with a tibial fracture and new acute dyspnea is likely to have suffered a pulmonary embolism. Transiently increased airway resistance can occur in patients with emboli as a result of bronchoconstrictive amines released from the embolus and of changes in alveolar gas composition due to reduction in regional blood flow. Dyspnea is associated with increased depth and frequency of ventilation, two factors that increase global airflow and decrease xenon clearance time.

The 25-year-old man with massive internal injury is at risk for adult respiratory distress syndrome characterized by interstitial edema and alveolar flooding, secondary to increased permeability at the alveolar-capillary interface. This change in permeability would be reflected by an increased rate of pulmonary clearance (reduced clearance time) of inhaled ^{99m}Tc DTPA aerosol, or an increased rate of pulmonary accumulation of intravenously administered ^{99m}Tc albumin. The presence of interstital fluid causes stiffening of the alveolar wall and decreased compliance.

The 40-year-old woman with idiopathic pulmonary fibrosis is likely to demonstrate the typical pathologic features of this disorder, which include increased interstitial deposition of collagen and elastin as a result of chronic inflammation and fibrosis. As a consequence of these changes, alveolar compliance is significantly decreased. Although airway diameter may be slightly reduced, airway patency is maintained by increased lung elastic recoil. Xenon clearance rates vary according to the extent of the disease process in different lung regions, but clearance rates tend to be in the normal range because of the counterbalancing effects on clearance time of reduced complicance and increased resistance.

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Items 16-20 Pulmonary Ga Scintigraphic Patterns

Answers: 16, C; 17, E; 18, A; 19, B; 20, D

Primary lung cancer with mediastinal metastasis would be the best explanation for the finding of a right middle lobe focus of ^{67}Ga uptake and several small mediastinal foci. Although intense uptake in the right middle lobe could be related to a tumor with postobstructive consolidation, a bacterial pneumonia would be the most likely cause of a well-defined lobar uptake pattern. All of the other patterns consist of bilateral gallium localization. Although bilateral primary tumors are possible, they are uncommon. There is

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SELF-STUDY TEST
Pulmonary Nuclear Medicine

ANSWERS

no pattern specific for sarcoidosis, but bilateral hilar and paramediastinal uptake is often noted in this disease. It is not uncommon to see parenchymal disease due to sarcoidosis in conjunction with hilar uptake, even in the absence of radiographic infiltrates. Opportunistic infection and other chronic interstitial processes uncommonly cause gallium uptake in mediastinal lymph nodes. Chronic interstitial diseases most often show diffuse but irregular uptake in the lung due to the patchy nature of the alveolar inflammation and fibrosis associated with the majority of these disorders. Opportunistic infections, and particularly *Pneumocystis carinii* pneumonia, on the other hand, generally show intense, diffuse pulmonary uptake of ^{67}Ga.

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For further in-depth information, refer to the syllabus pages in Nuclear Medicine Self-Study I.