Inhalation Lung Scanning Evaluation – Radioaerosol Versus Radioxenon Techniques*,**

Elaine M. Shibel, M.D.,† Glen A. Landis, M.D.,§ and Kenneth M. Moser, M.D., F.C.C.P.||

The routine study of regional ventilation of the lungs has been hampered by the lack of safe, simple and accurate methods. Radioisotope techniques have made possible the development of such methods. Two varieties of radioactive scanning have been used: radiolabelled particulate material, and radioactive inert gases. We have performed scans using both inhaled technetium-99m albuminate particles and xenon 133 gas. Normal subjects and patients with pulmonary disease were studied. Particle inhalation in normal controls revealed adequate peripheral filling, although upper airway and gastrointestinal deposition occurred. In patients with pulmonary disease, however, underventilated zones of lung appeared totally unventilated with particle scans, while those with 133Xe gas reflected ventilation disturbances more accurately. Further, a dynamic visualization of ventilation could be obtained using 133Xe, while scans with 99mTc albuminate indicated the cumulative result of several minutes of positive pressure breathing. It is concluded that both methods can offer important information, but each has its own limitations and advantages which should be recognized. Valuable insights into respiratory physiology and pathogenesis of pulmonary diseases can be obtained from these new techniques.

**INTRODUCTION**

Multiple recent investigations have emphasized that imbalance between pulmonary ventilation and perfusion is the dominant physiologic problem in a wide variety of pulmonary diseases.1,2 From such investigations has emerged recognition that detection and quantitation of ventilation/perfusion (V/Q) relationships has pertinence not only to the understanding of pulmonary dysfunction but also to patient management. Therefore, study of V/Q is now of significance to the clinician as well as the physiologist.

*From the Pulmonary Division, Department of Medicine, and the Radioisotope Unit of the Georgetown University Medical School, Washington, D.C.
*This work was supported in part by grants from the American Medical Association Education and Research Foundation, the American Thoracic Society and the Bezalel and Breth Foundations.
†Pulmonary Trainee, National Heart Institute, National Institutes of Health (HE5655). Present address: University Hospital of San Diego County, 225 W. Dickinson St., San Diego, California.
§Post-Doctoral Fellow, National Heart Institute, National Institutes of Health.
||Career Development Investigator of the National Heart Institute, National Institutes of Health; Associate Professor of Medicine, University of California, San Diego School of Medicine.

One reason for the rapid growth of knowledge about V/Q relationships has been the development of methods which permit graphic, serial measurements. Particularly useful have been those methods employing radionuclides. Appropriate techniques now permit not only calculations of V/Q ratios,3,4 but also visual display of the distribution of ventilation and perfusion by lung photoscanning.

Visual display of the distribution of pulmonary perfusion via photoscanning has now been explored extensively, using such radionuclide materials as macroaggregated albumin (labeled with 131-Iodine or 99mTc-Technetium), 113Indium particles, and 133Xenon gas injected intravenously. There is general agreement as to the qualitative and quantitative significance of such “perfusion” photoscans.6,8 Photoscanning has been less widely applied for evaluation of the distribution of ventilation, though it is already apparent that this procedure can supply useful information. However, two rather different methods have been used to obtain images representing ventilation distribution: one employs inhalation of particulate radiolabelled material;9-12 the other, inhalation of radioactive gas.13,14 We have
compared these two techniques in normal and abnormal subjects to determine whether each provides a similar photoscan image and, if not, how the information derived from each technique might differ. Since clinical inferences are now being drawn from both types of inhalation scans, such clarification seems essential if interpretive error is to be avoided.

**MATERIALS AND METHODS**

Scans were performed on 11 normal subjects and 25 selected patients with pulmonary disease, most commonly chronic obstructive pulmonary emphysema. Of the normal subjects, seven had inhalation scans with particulate Technetium (99mTc) albuminate and perfusion scans with radiiodinated macroaggregated albumin (131I MAA). Four had inhalation scans both with particulate 99mTc albuminate and with radioxenon (133Xe) gas.

Perfusion scans were performed in routine fashion, by means of intravenous injection of 131I MAA. Half the dose was administered in the supine position, half in the prone position.

Inhalation scans were done using 99mTc albuminate in saline solution. 5 mc in 5 to 10 ml. The solution was nebulized with a Bird Mark VII respirator. The patient was seated comfortably, with mouthpiece and noseclip applied. Nebulization was continued until all the solution was gone from the nebulizer, usually requiring from 10 to 20 minutes. Patients were encouraged to breathe slowly and deeply. Tubing from the expiratory line of the respirator was directed to an exhaust fan, which removed the expired air from the room environment. Following nebulization, all were given water to drink to insure that no radioactive particles were retained in the esophagus.

For radioxenon scans, 25 mc of gaseous 133Xe were placed in the bell of a Collins spirometer along with five liters of 100 percent O2. A fan was attached, assuring that uniform distribution of the O2-133Xe mixture was present throughout the system. Equilibrium was considered present when a stable count rate was recorded on a counter on the inspiratory line.

The patient was seated with his back to the camera, mouthpiece in place and noseclip applied, breathing room air. At the end of a normal expiration (the top of functional residual capacity), the valve was opened to the spirometer and the patient instructed to take a slow, deep inspiration to total lung capacity and hold his breath for 30 seconds. During this time, two 15-second scintiscans were taken. Nearly all patients were able to complete a 30-second breath-hold, and in those who could not, one 15-second picture was taken. Following this, the patient breathed normally in the closed system until equilibrium was reached between respiratory passages, spirometer and connecting apparatus. Further scans were obtained during this equilibrium state. The patient was then allowed to breathe room air again, permitting washout of the 133Xe to occur. Scans were taken for 15-second periods until insignificant amounts of radioactivity remained in the lungs.

All scans were done with the Anger scintillation camera. In most instances a divided crystal was used so that the separate counts could be obtained from each lung.

131I MAA perfusion scans and 99mTc albuminate inhalation scans were taken in posteroanterior (PA), anteroposterior (AP), and both lateral projections. 133Xe scans were taken only in the PA projection.

**RESULTS**

**Normal Subjects**

In the normal subjects, uniform distribution of injected 131I MAA was present. Inhalation of particulate 99mTc revealed generally uniform distribution as well, with good peripheral distribution of activity. In most, activity was also present in the trachea, mainstem bronchi and stomach (Fig 1).

**DIS. CHEST, VOL. 56, NO. 4, OCTOBER 1969**
also showed even distribution on both the initial deep inspiration (Fig 2A) and the equilibrium pictures (Fig 2B). Washout scans revealed rapid (within 30 to 45 seconds) dissipation of radioactive material, all areas of lung emptying at approximately the same time (Fig 2C).

Abnormal Subjects

$^{131}$I perfusion scans in the 25 patients showed variable patterns, depending on the disease process and its severity. Most emphysema patients had patchy defects scattered throughout both lungs, although a few showed larger defects, especially in areas where bullae were known to be present.

In patients with localized disease, inhalation scans with $^{99m}$Tc showed an essentially normal pattern, except in the affected portion of lung. Fig 3 shows the scan of a patient whose lungs were normal, but who had a large empyema in the right lower chest. Patients with generalized lung diseases, especially emphysema, demonstrated several patterns. Many had very bizarre looking $^{99m}$Tc albuminate scans, with large clumps of radioactive material remaining in proximal airways and little penetrating to peripheral tissues (Fig 4A, 5A). Some zones contained no radioactivity at all, suggesting that they were completely unventilated.

Initial deep inspiratory $^{133}$Xe scans in such patients usually revealed patchy underventilated zones. Many of these corresponded to areas which, on the $^{99m}$Tc albuminate scans, had appeared totally unventilated (Fig 4B, 5B).

On equilibrium $^{133}$Xe scans, zones which were poorly ventilated often filled slowly, so that after a variable period of time, nearly normal-appearing distribution of radioactivity was achieved (Fig 4C, 5C). On washout, these zones usually retained activity longer, so that dissipation of gas was uneven (Fig 4D, 5D).

Underventilated regions of lung demonstrated on $^{133}$Xe scans frequently corresponded well with underperfused areas seen on $^{131}$I MAA perfusion scans (Fig 4E, 5E).

Discussion

The development of a means of providing a visual presentation of pulmonary ventilation has been recognized as a new and valuable tool in the assess-

![Figure 3](http://journal.publications.chestnet.org/pdfaccess.ashx?url=/data/journals/chest/21482/) 

![Figure 4](http://journal.publications.chestnet.org/pdfaccess.ashx?url=/data/journals/chest/21482/)

DIS. CHEST, VOL. 56, NO. 4, OCTOBER 1969
ment of pulmonary disease. As previously mentioned, regional V/Q ratios are altered in many disease states. A technique for providing a rapid qualitative evaluation of regional pulmonary ventilation in clinical situations, therefore, has considerable value.

Both particulate aerosols tagged with radionuclides and inhaled radioactive gas techniques have been widely used to achieve such a visual presentation. The information derived from these studies may be applicable in the diagnosis and management of numerous clinical conditions. Both techniques have a valuable role to play in providing such information.

It is, however, valid to stress the fact that because of inherent differences in the two methods, the information supplied by each is not identical. Each has its advantages and limitations. Our study was designed to explore these differences and to emphasize the role of each technique in clinical practice.

With regard to the use of radiolabelled particulate aerosols, it has been recognized that particles of 0.06 μ to 2 μ in diameter can penetrate to distal airways and alveoli. Radioactivity has been demonstrated in alveoli of dogs killed after aerosolization of such particles.8,10 These dogs had normal lungs and were intubated for nebulization. That particles of the appropriate size are produced by commercially available nebulizers has been assumed, though not proven definitely under clinical conditions.

It has also been recognized that factors other than particle size play an important role in the pulmonary distribution of nebulized particles. These include concentration of aerosol, rate of air flow and, most important, turbulence in airways.10,16 Turbulence is accentuated in areas of partial bronchial obstruction, thereby potentiating deposition of particles in such areas and diminishing the number which penetrate beyond. Thus, although some ventilation may occur in alveoli distal to such bronchi, radioactive particles may not reach them. In such cases, zones of lung which are poorly ventilated would appear to have no ventilation whatever, while bronchi supplying them would have heavy concentrations of radioactive materials.

Patients with diffuse lung diseases such as emphysema tend to have many areas of lung in which such conditions exist. Although some airways may be completely obstructed, most affected bronchi or bronchioles are only partially obstructed, to greater or lesser degree, and some ventilation does occur beyond them. Repeating the scintiscan four to six hours later may, in some instances, result in a picture which more closely approximates regional ventilation.

The aerosol inhalation scan, therefore, although providing a fairly accurate picture in the patient with normal airways and lung parenchyma is not completely valid as a measure of regional ventilation in the patient with chronic obstructive airway disease.

The inhalation of a radioactive gas, on the other hand, simulates the usual conditions of ventilation. Gas molecules are not inhibited in their passage through the airways.
through small airways in the same way as are particles. If areas of poorly ventilated lung are present, they can be expected to appear as such on $^{133}$Xe inhalation scans. Our studies have shown that they do, in contrast to $^{99m}$Tc albuminate scans in the same patients, where these areas sometimes appear totally unventilated (Fig 5A, B). Further, no visualization of trachea, mainstem bronchi, and stomach occurs in $^{133}$Xe scans as it does with $^{99m}$Tc, even in normal subjects (Fig 1, 4A, 5A). These artifacts may suggest that ventilation is poor when, if fact, it is not. They may be minimized by careful instruction of the patient in slow deep breathing, and by production of the smallest possible aerosol particles, as with an ultrasonic nebulizer.

$^{133}$Xe scans require the use of a rapid-imaging device such as a scintillation camera, since counts must be taken rapidly. Even the fastest rectilinear scanner cannot take 15- or 30-second pictures. For this reason, in centers where such a camera is not available, only aerosol scans can be done. Important information can be derived from these. However, the limitations of this type of scan should be recognized.

In addition to the pattern of ventilation demonstrated by $^{133}$Xe inhalation scanning, another advantage is the ability to display dynamic pictures of ventilation during both the equilibrium and washout phases. An underventilated area picks up radioactivity more slowly than normally ventilated lung and washes out more slowly as well. The aerosol “inhalation” scan, on the other hand, provides a static picture representing the cumulative result of several minutes of breathing.

One disadvantage of the $^{133}$Xe scan is that with current equipment only one projection can be obtained at a time. The study must be repeated to obtain other views. In our patients, all scans were performed in the PA projection. It must be stated that this view is not adequate and further information is frequently derived from AP and lateral projections.

A potential objection to $^{133}$Xe ventilation scanning, that it is difficult for emphysema patients to maintain full inspiration for an adequate time period, has not been a problem in our experience. Nearly all can hold a deep inspiration for 30 seconds, and when this is not possible, for at least 15 seconds. When an adequate concentration of $^{133}$Xe is present in the Xe-O$_2$ mixture, satisfactory pictures can be obtained in this time.

The $^{133}$Xe ventilation scan, thus, provides a simple, accurate and dynamic picture of regional pulmonary ventilation in both normal and abnormal subjects. The radiation dose is minimal. Although our objective was not to obtain quantitative data, the technique can be expanded from a visual presentation to provide quantitative measurements of ventilation in smaller zones of lung. Furthermore, quantitative ventilation/perfusion ratios for various regions of the lung can be calculated when $^{133}$Xe inhalation is combined with perfusion scanning.

If quantitation is desired, other considerations arise. Special attention must be paid to phase of respiration (lung volumes). Both ventilation and perfusion scans must be performed in the same position. Uptake of inhaled radioxenon by capillary blood during breath-holding must be considered.

While quantitation is desirable, however, the clinical implications of the described techniques are many. Qualitative delineation of ventilation/perfusion ratios on a routine basis will allow more accurate evaluation of the patient and more rational assessment of therapeutic measures.

References

Dis. Chest, Vol. 56, No. 4, October 1969

Downloaded From: http://journal.publications.chestnet.org/pdaccessashx?url=data/journals/chest/21482/ on 06/24/2017


Reprint requests: Dr. Shibel, University Hospital of San Diego County, San Diego 92103.