The Lung Scan in Patient Selection for Lung Volume Reduction Surgery

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The lung scan is one of the most important diagnostic tests used for selecting candidates for lung volume reduction surgery (LVRS) and for determining the actual percentage of lung to be resected during the surgery (McKenna R, *personal communication*, 1997). This article describes the anatomical quantitation of the lungs.

Methods: We used automatic and manual regions of interest in the posterior, and both posterior obliques of lung perfusion images to calculate the percent function in each individual lung lobe.

Results: We evaluated 172 patients with this technique. Subsequently 136 of these patients had LVRS.

Conclusion: The anatomical placement of regions of interest in the lung perfusion image aids the thoracic surgeon in selecting LVRS candidates and in determining the amount of lung to be resected during surgery.

Key Words: technetium-99m-MAA; xenon-133 gas; lung volume reduction surgery; quantitative lung imaging

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Emphysema is a pathologic accumulation of air in tissues or organs (*1*). In pulmonary emphysema the lung slowly loses its normal elasticity over a long period of time. Eventually this causes the lung to trap air that leads to hyperexpansion of the lungs until there is no longer room inside the chest cavity to take a deep breath. The patient thus becomes dyspneic.

Maximal medical management, including pulmonary rehabilitation, has had a small impact on quality of life and dyspnea, but no impact on breathing. Recently, lung volume reduction surgery (LVRS) has been shown to improve pulmonary function in emphysema patients as well as provide a positive change in their lifestyle (*2–4*).

LVRS for severe emphysema was pioneered by Bratigan and Mullen in the late 1950s, but due to a high death rate (16%), this type of surgery never became popular (*4,5*). Recent improvements in surgical technique have reduced the death rate. This in turn has made many thoracic surgeons and emphysema patients regain interest in this type of treatment (*5*).

Successful outcome of patients undergoing LVRS is based on proper patient selection as well as an active rehabilitation program after the surgery (*5*). At present, only one of four patients presenting with severe emphysema is recommended for surgery (*5*).

The selection process these patients undergo before surgery includes the following criteria. The patient must be under 80 yr of age, be a nonsmoker, not have a history of cancer diagnosed within the previous 5 yr, not have a history of severe heart disease, and not be ventilator dependent (*6*). The patient must be symptomatic despite having maximal medical, pharmaceutical and therapeutic treatments, and must have a series of pulmonary function tests to assess the amount of dyspnea. There is also an evaluation of the patient's lifestyle during this screening process (*4–6*).

The patient must have a preoperative three-view chest radiograph (AP-inspiratory, expiratory and lateral) to show the displacement of the diaphragm, a CT scan of the chest, and a ventilation and perfusion lung scan. These must show a severely heterogeneous pattern of emphysema localized predominantly in the upper or lower lobes. There may be discrete areas localized on both the upper and lower lobes of the lung or lungs (*4–6*).

The surgical procedure removes the most damaged tissue so that the remaining tissue can function more effectively. One important tool for the thoracic surgeon is the anatomically quantified perfusion lung scan, which shows the delineation of the different lobes of the lungs at first sight, describing the particular areas lacking substantial blood flow. To date, we have used this technique to evaluate 172 patients.

MATERIALS AND METHODS

A single-head digital gamma camera with a low-energy all-purpose collimator was used to obtain the ventilation and perfusion images. The patients were imaged predominantly in the supine position. Xenon-133 was used for the ventilation study. Technetium-99m-MAA was used for the perfusion scan. After all the images were obtained, an automatic lung ratio

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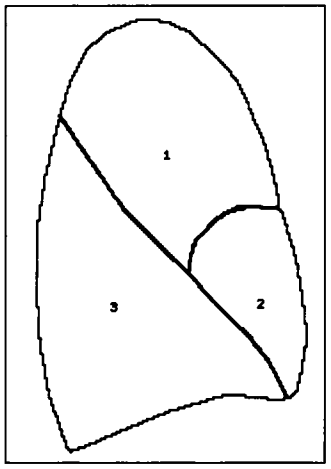

FIGURE 1. Drawing of right lung, defining the anatomical location of the upper, middle and lower lobes.

program was applied to the posterior perfusion image and percentages of perfusion to each area were obtained.

Manual regions of interest (ROIs) were drawn on both posterior oblique images of the perfusion scan. Then the counts for each ROI were used to calculate the percentage of blood flow to each drawn region using the following formula: individual lobe counts/total lung counts × 100 = % perfusion for that particular lobe.

Anatomy

A brief overview of lung anatomy will help in understanding anatomical ROI drawing. The lungs are two conical structures of spongy tissue localized in the thoracic cavity. The most superior part of the lungs are the apices and the most inferior part of the lungs are the bases, delineated by the costophrenic angles.

The right lung is divided into three lobes called the upper, middle and lower lobes. The lower lobe appears largest in the lateral or posterior oblique views (Fig. 1). The left lung is composed of only two lobes, the upper and lower lobes (Fig. 2). Between each lobe are the fissures. These usually are seen clearly in the posterior oblique images of the perfusion scan, facilitating the drawing of the different ROIs described later in this article.

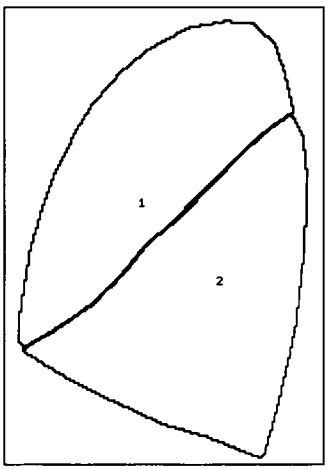

FIGURE 2. Drawing of left lung, defining the anatomical location of the upper and lower lobes.

Patient Preparation

No specific patient preparation is required. Patients should abstain from any gaseous liquids, like sodas, which would expand the stomach. This causes even more pressure on the diaphragm and, therefore, more dyspnea.

Knowing that patients with emphysema have long, overinflated lungs, meaning that the length of the lung from apex to diaphragmatic angle is larger than the normal individual, it is preferable that the ventilation and perfusion scan be done in the supine position. This elevates the diaphragm and allows the whole lung to fit in the field of view. If it is absolutely necessary to perform the study in the upright position, care should be taken to include the area of interest in each case. Most candidates for LVRS have predominant upper lung disease (*5*). If one is not sure, check with the ordering physician, because frequently the physician and sometimes even the patient know which areas of the lungs are involved.

When centering the patient to the camera, it is best to first carefully examine the patient's posture and demeanor. Most patients, especially men, have elevated shoulders because this position reduces dyspnea. Place the top of the field of view about 0.5 inch above the clavicle.

Ventilation Scan

Emphysema patients have severe damage to the lung tissue, and mucous secretions are common. For this reason, only ^{133}Xe gas should be used for the ventilation study. With any aerosol product, the particulate will deposit in the tracheobronchial tree with minimal penetration into the lungs due to poor movement of air through large spaces found in this disease (Mitchell R, *personal communication*, 1997). This creates a patchy image that is of no use to the thoracic surgeon.

Most candidates for LVRS are elderly patients with a mean age of 68 yr (*5*). A mask, rather than a mouthpiece, works best for emphysema patients, unless he or she feels too uncomfortable.

Our protocol includes 7.5–10 mCi ^{133}Xe inhaled in one single breath-hold image, for no longer than 15 sec (most emphysema patients cannot hold their breath that long). Two equilibrium images continue at 20 sec each, followed by seven washout images at 20 sec each and one final image postwashout for 120 sec.

It is important to remember that emphysema patients trap gas, so their washout is much longer than the patient with normal pulmonary function. It is, therefore, suggested that the mask be kept on the patient longer to allow the xenon-trapping device to recover as much xenon returning from the patient as possible.

Perfusion Scan

As with any other perfusion scan, the patient should be injected in the supine position. We use between 3.5 and 5 mCi ^{99m}Tc-MAA administered intravenously.

The usual images should be obtained, with or without anterior obliques. Caution should be taken when imaging the posterior obliques so as to minimize superimposition of the lungs.

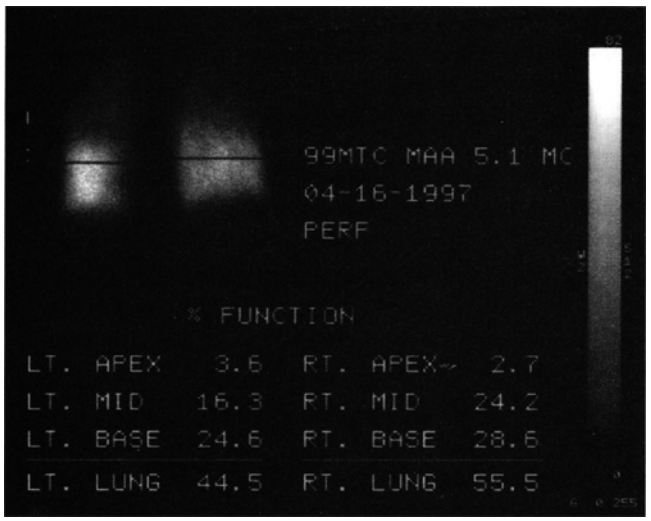

FIGURE 3. Image of a posterior perfusion scan on a patient with bilateral bullous emphysema of both upper and part of the mid lung fields. The automatic ROIs and the subsequent percentage of function values are given.

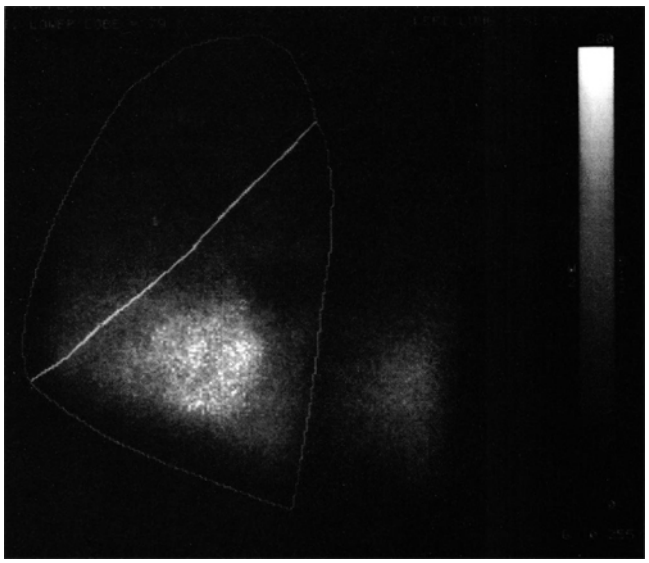

FIGURE 5. The placement of manual ROIs in the upper and lower lobes of the left lung. Functional values were upper lobe 21% and lower lobe 79%.

This provides a more accurate result when the manual oblique ratios are obtained.

Placement of ROIs and Calculation of Lung Ratios

As detailed above, ratios should be obtained in the posterior as well as both posterior oblique images as shown in Figures 3, 4 and 5. The oblique views especially provide a more anatomically correct look at the location of each lobe in the particular patient.

The posterior ratios can be performed automatically, if equipment permits, or manually. The ratios on the oblique views should be done manually to adjust for variation in body habitus. The ROIs should be placed in each lung as anatomically correct as possible. The lack of perfusion in one area does not mean that there is no lung tissue there. This area of the lung should not be excluded from the ROI. To facilitate drawing the ROI, the intensity should be increased so that the contours of the lungs may be seen. The lateral view helps to determine the anatomical configuration of each lobe and facilitates placing the ROI.

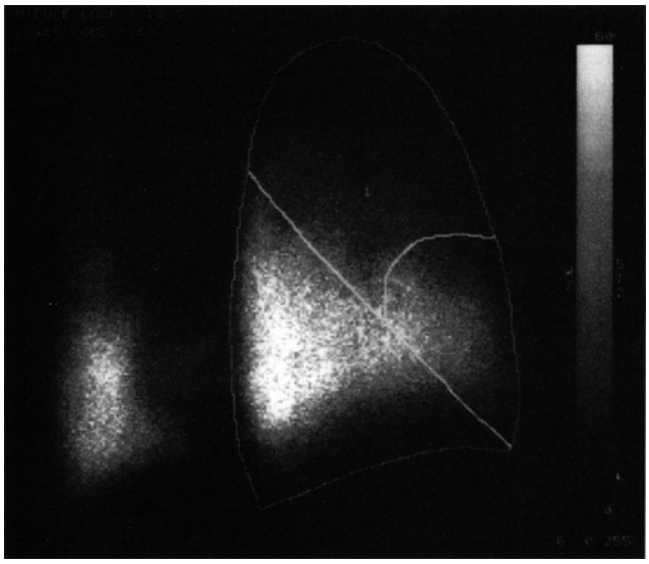

FIGURE 4. The placement of manual ROIs in the upper, middle and lower lobes of the right lung. Functional values were upper lobe 19%, middle lobe 18% and lower lobe 63%.

Notice that on the right lung, the middle lobe is usually considerably smaller than the upper and lower lobes. Deformity of the lobes is expected in patients with emphysema due to the hyperinflation of the lungs. This is usually symmetrical and is easily determined. Keeping a sample of the anatomical placements of the ROIs for reference can help guide the technologist with difficult cases.

Next we add the counts for each ROI, one lung at a time, to get a total count. Divide each segmental count by the total counts and multiply it by 100, to determine the percentage of blood perfusion for each ROI in that lung. Repeat this for the opposite lung. A total percentage for each lung also should be calculated.

RESULTS

We have evaluated 172 patients. A total of 136 patients had LVRS, while 36 were not surgical candidates. The most common reason that patients were excluded as surgical candidates was the absence of severe heterogeneous emphysema (n = 20). The ventilation-perfusion lung procedures were used to confirm the presence or absence of a severe heterogeneous pattern seen on CT and to quantitate the degree of heterogeneity. The remaining patients were not surgical candidates for other reasons. Patients who had LVRS all showed a severe heterogeneous pattern (Fig. 3). Patients with diminished ROI functional measurements in the upper or lower lobes were considered to have a heterogeneous pattern.

CONCLUSION

Xenon-133 lung ventilation and ^{99m}Tc-MAA perfusion imaging provide valuable information to the thoracic surgeon. These procedures help qualify a possible candidate for LVRS, and provide the thoracic surgeon with the location of the most diseased area of the lobe and the amount of lung resection necessary to best benefit the patient.

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