Fourier Phase Analysis of First-Pass Data: Noninvasive Detection of Pulmonary Sequestration

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Nuclear medicine Fourier phase analysis of first-pass data was used to evaluate blood flow to cystic lung masses in two children suspected of having pulmonary sequestrations. In both cases, the Fourier images provided a rapid, noninvasive, inexpensive analysis of the blood supply to the masses and permitted identification of the masses as pulmonary sequestrations. The analysis does not depend on the location of the mass and demonstrates the location of systemic rather than pulmonic arterial blood supply to the mass. In one case, Fourier analysis identified a second source of systemic blood supply not visible with other imaging modalities. Preoperative assessment of a cystic lung mass using Fourier analysis enables noninvasive classification of the mass as a pulmonary sequestration with systemic blood supply and aids the surgeon in resection.

Key Words: pulmonary sequestration; Fourier phase analysis; technetium-99m-DTPA; radionuclide angiography; lung

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Pulmonary sequestration is a congenital abnormality in which a segment of lung develops without normal connection to the tracheobronchial tree. The separated mass has systemic rather than pulmonary arterial blood supply (*1–5*). Infants may present asymptomatically but with abnormal chest radiographs or with recurrent pneumonias. Typically, chest radiographs and even CT reveal a cystic mass in the lungs, but do not readily differentiate the mass as a sequestration. Identifying the blood supply of a pulmonary sequestration from a systemic source is a diagnostic hallmark and provides important information for the surgeon undertaking resection.

Radionuclide angiography (RNA) is frequently successful in detecting pulmonary sequestration during a first-pass flow study of the heart and lungs (*6–8*). The sequestration may be seen as an area of lung having a relative lack of perfusion during the pulmonary arterial phase followed by perfusion during the systemic phase. Unfortunately, delineation of the mass on the RNA images is often not as clear and convincing as desired.

Fourier phase analysis is most commonly used to evaluate data from gated blood-pool cardiac studies that include data from emptying and filling cycles of the left ventricle. It has been shown previously that Fourier phase analysis is helpful in the interpretation of non-cyclic, dynamic flow studies (*9*). While the data from pulmonary sequestration are not cyclic, a single harmonic cosine Fourier analysis is nonetheless possible and provides an extremely effective method for analyzing any flow study. The amplitude image provides a good estimate of the magnitude of flow to any given area. By using the phase image, it is possible to identify when flow to an area occurred.

In the case of pulmonary sequestration, the key issue is whether the mass is perfused by pulmonary or systemic arterial blood. Fourier phase analysis easily and cleanly differentiates these two kinds of arterial perfusion.

We report the cases of two children with surgically proven pulmonary sequestration. The diagnosis of pulmo-

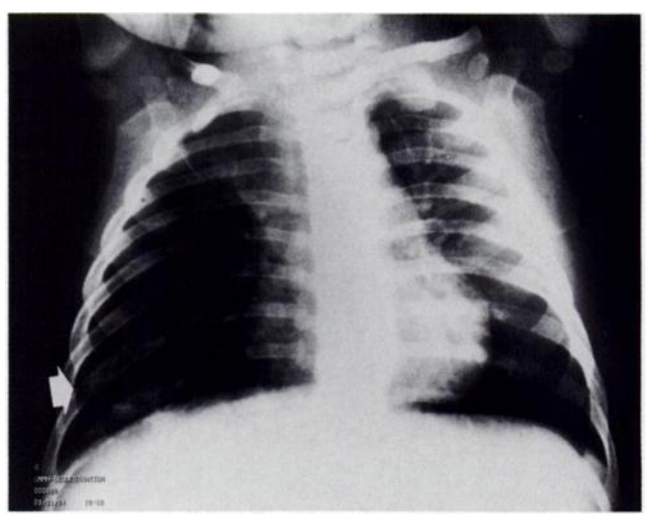

FIGURE 1. PA chest x-ray of Patient 1 showing partially cystic density in right lower lung field (arrow).

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nary sequestration was made noninvasively in both cases by means of Fourier phase analysis of first-pass RNA.

PATIENT ONE

A 7.5-mo-old male presented with a history of recurrent, right lower lobe pneumonias. A chest radiograph (Fig. 1) and a CT scan (Fig. 2) revealed a cystic mass in the right lower lobe of the lung. A first-pass RNA study was performed using 1 mCi of ^{99m}Tc-DTPA injected through the right external jugular vein (Fig. 3). Because of the small size of both the patient and the mass, the standard RNA flow images did not convincingly show the sequestration. Subsequent Fourier analysis of the flow data clearly demonstrated that the right lower lobe lung mass was perfused by systemic blood from the aorta rather than pulmonary arterial blood (Fig. 4).

The patient was taken for surgical resection, which confirmed that this was an intralobar sequestration in the right lower lobe with a systemic arterial blood supply.

PATIENT TWO

A 12-yr-old male known to have scimitar (venolobar) syndrome with partial anomalous venous return to the right atrium was suspected of also having a pulmonary sequestration. An aortogram done as part of a cardiac catheterization procedure showed an anomalous artery originating below the diaphragm. This vessel fed the right lower lung mass with systemic blood (Fig. 5).

A RNA study was done via injection of the right external jugular vein with 1 mCi of ^{99m}Tc-DTPA. Fourier phase analysis showed that the right lower lobe mass was perfused by systemic blood. The mass appeared on the phase images slightly after the left ventricle, but before the abdominal aorta was seen (Fig. 6). This suggested that an additional artery, more proximal than the artery already visualized on the aortogram, was also perfusing the mass. Careful review of the aortogram confirmed the presence of this vessel (Fig. 2C), which was previously assumed to be a diaphragmatic branch. In fact, it was an additional feeding vessel to the mass. This was critical information for the surgeon to know before surgery began.

DISCUSSION

Pulmonary sequestrations have been successfully imaged using a variety of modalities. These include CT, magnetic resonance angiography (MRA), MR, invasive contrast angiography, ultrasonographic Doppler studies and RNA (*3,10–13*).

CT exposes the patient to contrast, but does not always demonstrate the presence of systemic arteries (*14*). The procedure is both time consuming and expensive. MRA uses no radiation or contrast, but is more expensive and may be technically impossible if respiratory motion degrades the image quality. While MR imaging has been reported to demonstrate both arterial and venous blood supply, (*15*) this technique has not come into common use, is expensive and time consuming.

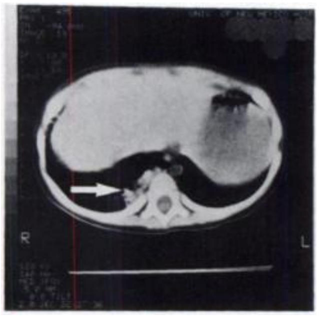

FIGURE 2. CT scan of Patient 1 showing lesion in right lower lung field (arrow).

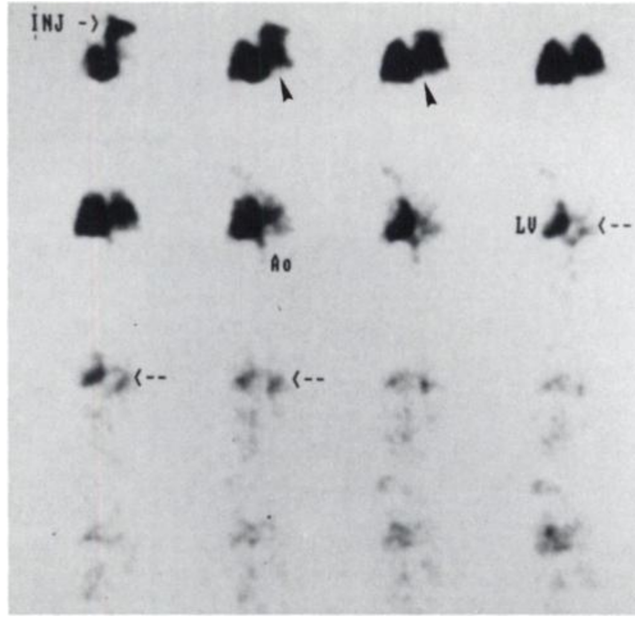

FIGURE 3. Posterior view of RNA study of Patient 1 showing lack of perfusion to right lung base (arrowheads) during pulmonary arterial phase, and systemic arterial perfusion later (arrow).

Contrast angiography is accurate in most cases but is undesirable because it is invasive. Color Doppler imaging has been used to demonstrate systemic arterial blood supply to sequestrations and the draining veins (*16,17*). Although the majority of pulmonary sequestrations are in the lower lobes (*3*), which are more accessible to ultrasound, the location of the sequestration may degrade the reliability of color Doppler imaging.

RNA is a sensitive technique that detects systemic blood flow to a pulmonary mass and confirms that it is consistent with a pulmonary sequestration. However, depending upon the size of the mass and the amount of blood flow to it, standard RNA flow images may not be sufficiently convincing.

The addition of Fourier phase analysis of the flow study data greatly enhances the sensitivity for detection, especially for smaller sequestrations. Furthermore, since this analysis is time related it assesses the source of arterial blood supply. In cases such as this, it provides additional detailed information about the blood flow to the mass. Using Fourier analysis adds no additional expense or radiation. It is quick, noninvasive, inexpensive and greatly improves diagnostic accuracy while reducing patient risk.

We recommend that Fourier analysis of first-pass RNA data be routinely performed on patients suspected of having a pulmonary sequestration.

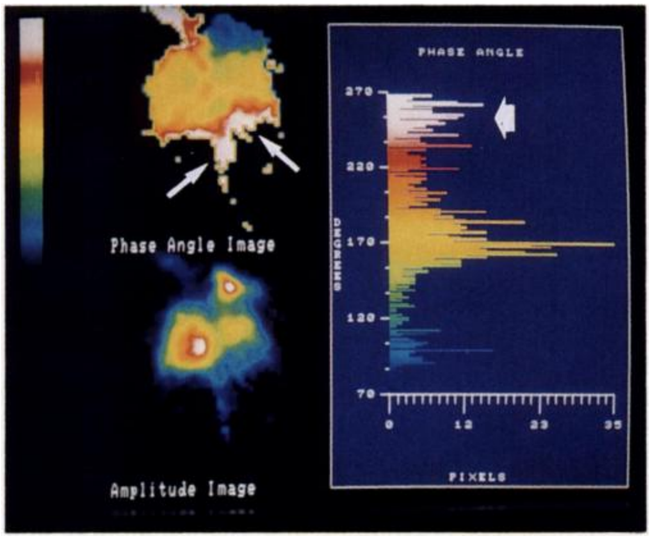

FIGURE 4. Fourier phase study of Patient 1 (posterior view). Arrows on phase image show activity in right lung base in same color (i.e., same time of occurrence) as visualization of abdominal aorta. Arrowheads show comparable occurrence on phase angle histogram.

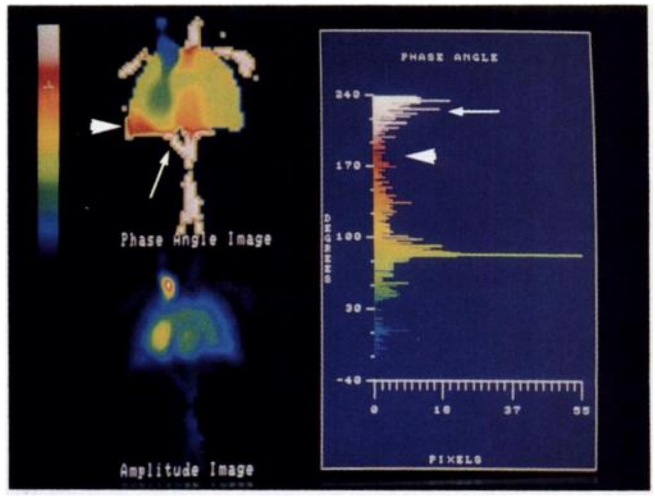

FIGURE 6. Fourier phase study of Patient 2 (anterior view). Arrows show anomalous vessel arising below the diaphragm on both the phase angle image and on the phase angle histogram (pink color). Arrowheads show activity on both the phase angle image and histogram in the region of the right lung base sequestration (red) occurring before the large feeding vessel below the diaphragm. This finding raised the suspicion of a second feeding vessel.

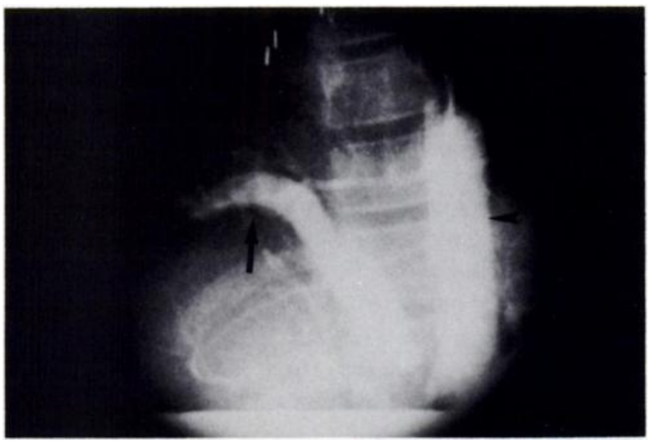

FIGURE 5. Anterior view of aortogram on Patient 2. Arrowhead shows descending aorta and arrow shows large anomalous vessel arising below the diaphragm and feeding the sequestration in right lung base.

FIGURE 7. A slightly earlier segment of aortogram than shown in Figure 5. The large anomalous vessel below the diaphragm is not yet filled. A second smaller vessel above the diaphragm is now seen (arrow) with a tumor blush in the sequestration (arrowhead).

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