Lungs SPECT image processing for Volume and Perfusion Index estimation

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Abstract - **In the evaluation of the lung status during pulmonary embolism and patient's follow up, accurate volume estimation is important In this study a method for lungs' volume determination by SPECT images and the definition of an index of perfusion scans homogeneity (LPI) are demonstrated.**

From lung perfusion SPECT data of 42 patients, volumes of reconstructed transverse slices were estimated by counting the voxels inside each slice. An edge detection program was used to mark the lung lobe's edge and subtract background. The total lung lobe volume was derived by summing the slices' volumes. Non uniform attenuation compensation was performed by quantitative filtered back-projection. A lung lobe segment volume analysis was also determined, in the same way, for the identification of lung section volumes with diminished radionuclide concentration and correlation of follow-up SPECT lung perfusion studies. Lung perfusion index (LPI) is the ratio of lung segment volume over the whole organ volume and indicates the severity of the lung section perfusion situation. Comparison of LPI of repeat scans in follow up studies constitutes the pulmonary improvement factor.

In order to evaluate the accuracy of these measurements, 5 cylindrical phantoms, [1000-1500] ml volume, containing Tc99m activity dispersed in simulated lung tissue (a mixture of styrofoam beds with water) were acquired under conditions similar to those of the patients' study. Using the regression equation derived from the phantom study, volumes of the lungs' lobes were computed.

The method is simple and fast with a relative error up to 3% for length, 11% for area and 8% for volume determinations. The precision of the estimate varied, depending on the size and clinical status of lung lobe.

We have developed a method, which assist to the accurate interpretation of perfusion scans by volume and semi quantitative lung perfusion index determination.

Keyword: SPECT data analysis, lung volume, perfusion index, image processing

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I. Introduction

Lung perfusion scintigraphy has been used as a diagnostic method for various pulmonary diseases. Specifically, it has been used for assessment of pulmonary emboli in patients with or without presence of chronic obstructive pulmonary disease and as part of routine follow-up evaluation of lung therapy for assessment of pulmonary emboli in patients with or without the presence of chronic obstructive pulmonary disease. Radionuclide perfusion scintigraphy remains an important diagnostic tool, not only in the diagnosis of perfusion emboli as an emergency tool but also in the assessment of regional function in a follow up procedure. The main strength of the perfusion scan is that it allows us to obtain quantitative information about perfusion of the lungs in a physiological way. Pulmonary embolism is a relatively common and potentially fatal disease. The incidence of deep venous thrombosis is approximately one in 1000 per year and about 50% of deep venous thromboses are complicated with pulmonary embolism. About 10% of patients with PE die within 1 h of the PE event. However, the treatment for pulmonary emboli with anticoagulants or surgery is highly effective, but complications occur frequently. Therefore, the accurate and prompt diagnosis is very important. The clinical picture of pulmonary emboli is non-specific, including sudden dyspnoea and hypoxemia, pleuritic pain, haemoptysis, substernal pressure, which may mimic coronary artery disease, other kinds of pulmonary diseases, gastroesophageal reflux, pleural disease or pericarditis. The risk factors for deep venous thrombosis in lower extremities and pulmonary embolism including inactivity/ stasis, status post surgery, presence of malignancy, oestrogen use, smoking and hyper coagulable state.

In the diagnosis of pulmonary embolism, chest radiography is not an accurate diagnostic tool. Most patients (88%) who have pulmonary embolism have abnormal but non-specific chest radiographic findings, including atelectasis and parenchymal areas of increased opacity

A diagnosis of pulmonary embolism with the perfusion scan is based on the presence of perfusion defects rather than on a direct visualization of the embolus. Therefore, the result of lungs' scintigraphy essentially can be regarded as a probability estimate of the presence or absence of

Pulmonary embolism that is based on the number and size of defects. Several well-defined interpretation schemes are used that divide lungs' perfusion scan probabilities in three or four categories from normal to high probability

II. Objective

Patterns of perfusion scans with Tc-99m Microspheres can provide an estimation of the extent of pulmonary embolism. Measurement of regional distribution of blood flow can help predict the consequences of lung resection or lung reduction surgery and cystic fibrosis, or radiation therapy. Four functional categories of lung pathology can be distinguished: the vascular occlusive state and the consolidative, obstructive, and restrictive states, resulting in scintigraphically detectable distortions of perfusion. Segmental or sub segmental hypo perfusion can be caused by obstruction of pulmonary vessels due to intra-or extra vascular pathology, including perfusion emboli.

Focal zones of relative hyper perfusion (hot spots) on perfusion scintigraphy can be seen which can lead to misinterpretation of the scan. The zones of apparent hyper perfusion may reflect true local vasodilatation or preserved perfusion in an area of normal lung adjacent to abnormal lung regions

Accurate volume determination is useful in the evaluation of the lung status in pulmonary embolism follow up. In this study, a method for lungs' volume determination by SPECT images and the definition of an index of perfusion scans homogeneity, Lung Perfusion Index (LPI) are demonstrated.

III Method

A GE SPECT gamma Camera connected to a new processing system GE XELERIS-2 has been used for acquisition processing and reconstruction of the obtained lung images both planar and tomographic.

Lungs' perfusion planar studies, by Tc99m microspheres, were completed to 42 patients after pulmonary embolism events. Semi quantitative measurements in posterior and anterior planar images, divided to three equal segments, were obtained to show acute situation and recovery after few days therapeutic schema.

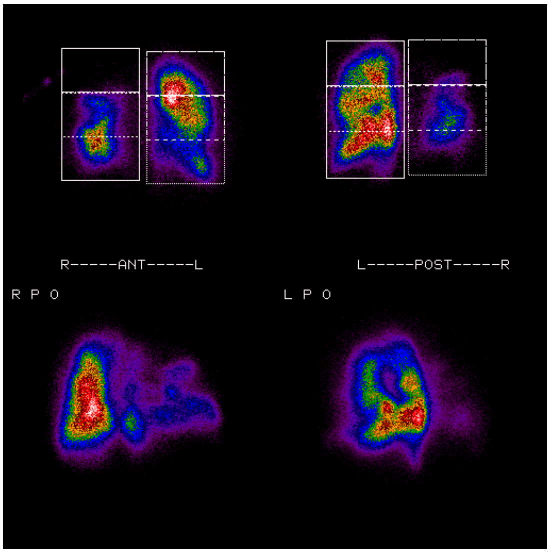

Image 1. Multiple acute lungs embolisms

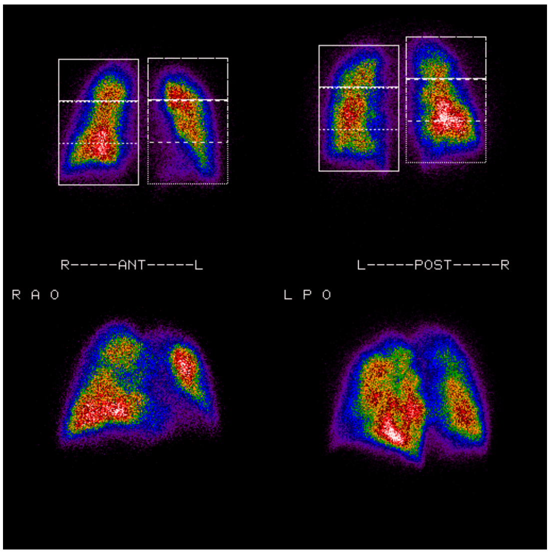

Image 2. 80% Recovery 11 days post therapy

By SPECT lung studies (data reconstruction in transverse, coronal, sagittal slices as well as three dimensional [3D] images) in 22 of our patients, we have measured the lungs' volumes. 12 of them had also series of follow up SPECT studies after the pulmonary embolism event, in order to estimate the lung perfusion improvement, quantitatively.

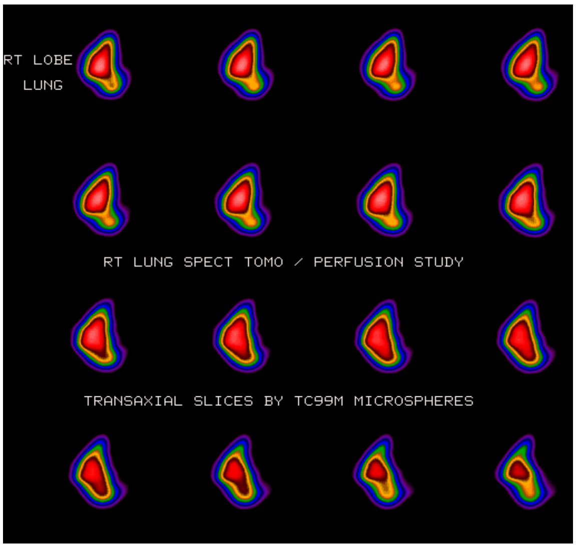

Image 3. Lung right lobe transaxial slices

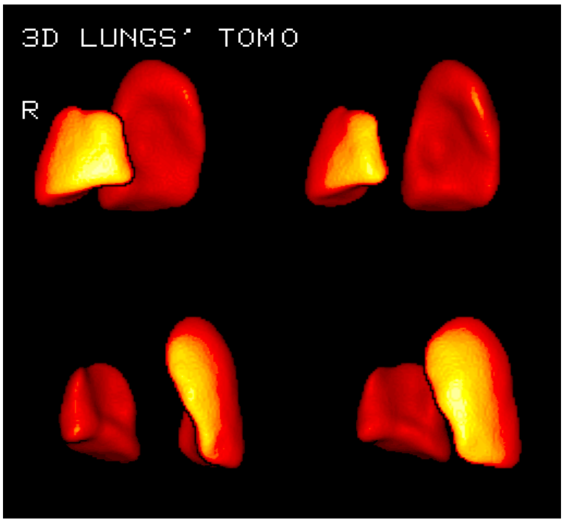

Image 4. Lungs' 3D tomography Lower lobe defect [9%],Upper right lobe perfusion defect (16% of total volume]

From lung perfusion SPECT data, volume of each reconstructed transverse slice was estimated by counting the voxels inside each slice. Our edge detection program was used to mark the lung lobe's edge and subtract background. Summing the slices' volumes derived the total lung lobe volume. Non-uniform attenuation compensation was performed by quantitative filtered back-projection. Image threshold 50% of data maximum was considered. A lung lobe segment volume analysis was also determined, in the same way, for the identification of diminished radionuclide concentration lung part volumes and correlation between follow-up SPECT lung perfusion studies.

Lung Perfusion Index [LPI] is the ratio of lung lobe or lung segment volume over the whole organ volume and indicates the severity of the lung part perfusion situation. Comparison of LPI of repeat scans in follow up studies constitutes the Pulmonary Improvement Factor [PIF].

PIF= recovery volume/ event time volume

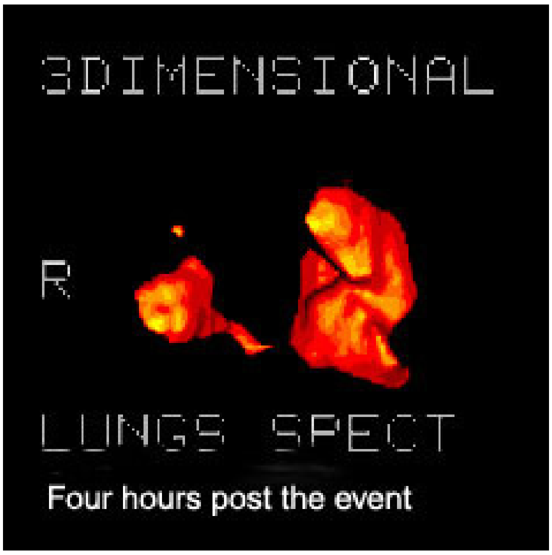

Image 5 Four hours post the event, Lungs' 3D tomography Rt lobe embolism, Rt Lobe volume: 0.66 lt Total Volume: 2.85 lt

Image 6. Eleven days post therapy Rt Lobe volume: 3.28 lt , Total Volume: 5.28 lt

Total Lung Pulmonary Improvement Factor [PIF]: 1.85(>1) scale up to 10

Rt lobe PIF: 4.97(>1) scale up to 5

Verification Stage

In order to evaluate the accuracy of these measurements, 5 cylindrical phantoms, [1000-1500] ml volume, containing Tc99m activity dispersed in simulated lung tissue (a mixture of styrofoam beds with water) were acquired under conditions similar to those of the patients' study. Using the regression equation derived from the phantom study, volumes of the lungs' lobes were computed.

Phantom images: Traansaxial, Coronal and 3D SPECT Phantom images Volume calculation accuracy: 4.8%

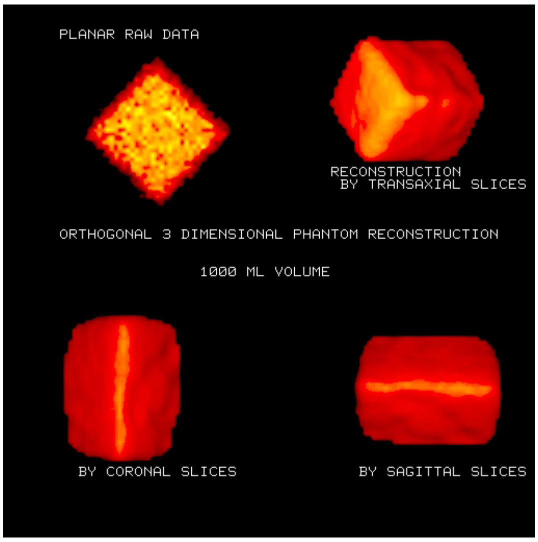

Image 7 Planar image & 3D phantom images reconstructed on different axis

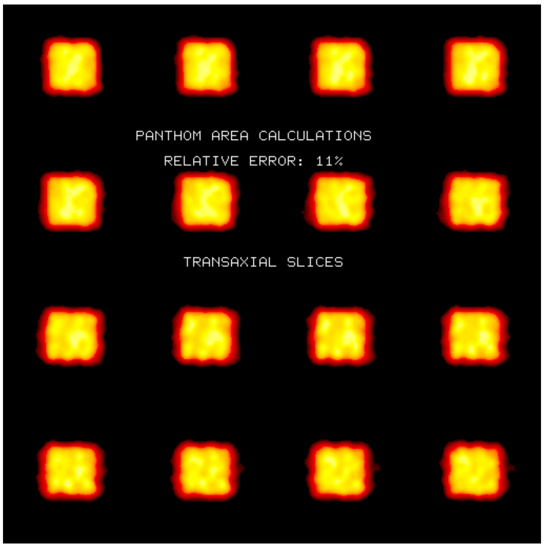

Image 8 Transaxial slices of phantom

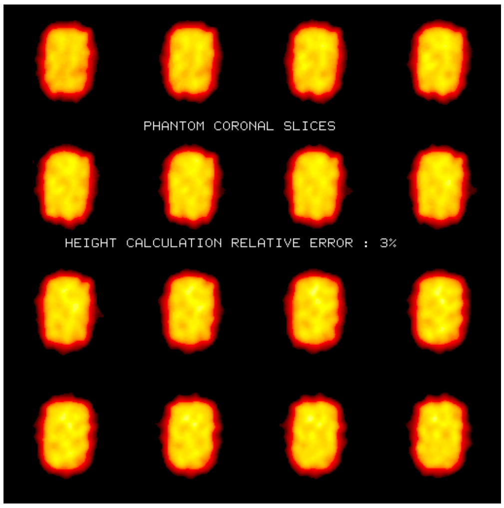

Image 9 *Coronal slices of phantom*

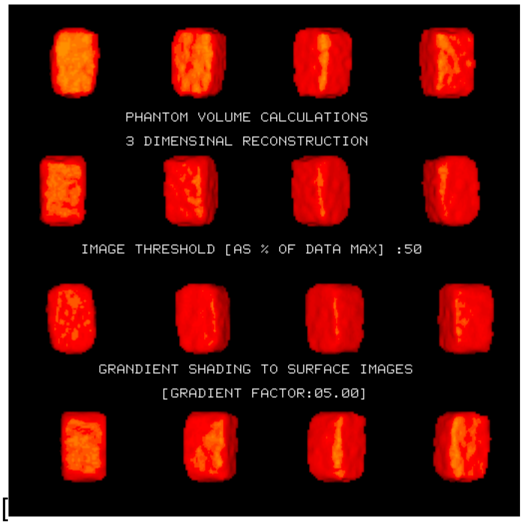

Image 10 3D SPECT Phantom images

IV. Results

SPECT perfusion scan were in moderate to good agreement for both the volume and severity of the radiotracer defect areas. The method is simple and fast with a relative error up to 3% for length, 11% for area and 8% for volume determinations. Lung Perfusion Index [LPI] indicates the severity of the lung section perfusion situation and Total Lung Pulmonary Improvement Factor [PIF] shows the improvement and progress in the follow up procedure. The precision of the estimate varied, depending on the size and clinical status of lung lobe.

V. Conclusion

Semi quantitative perfusion scintigraphic data may help select patients' therapy and function as a predictor of clinical outcome after pulmonary embolism. We have developed a method, which assist to the accurate interpretation of perfusion scans by volume and semi quantitative Lung Perfusion Index [LPI] and Pulmonary Improvement Factor [PIF] determination.

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