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Computer Processing of Pulmonary Function Data Obtained Using ^{133}Xenon and a Scintillation (Anger) Camera

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^{133}Xenon and a sciatillation (Anger) camera have have been used extensively in Nuclear Medicine Clinic durig the past four years forth evaluation of pulmonary function and for measurements of regional pulmonary blood flow (1, 2, 3, 4, 4, 5). Presently all data accumulated during these studies are processed by a computer (Control Data Corporation 3300).

Materials and Methods

One curie of ^{133}Xenon gasin a glass a ampule is received at weekly intervals from Oak Ridge National Labcratories. The gas is transferred into sterile saline solution by a technique which proviides cooncentrations up to 15 mc/ml (5). Our scintillation camera is fitted with a diverging collimator which permits both lungs to be viewed in their entrety, even for relatively larege patients. The bialkali cathode photomultipler tubes used to view the scintillation crystal have a relatively low work function for electron release, ro that acceptable statistical information on positioning of idividual scintillations is obtained from the relatively lowenergy gamma rays from ^{133}xenon (81 keV).

Pulmonary functon studied out with the patient either in the upright or supine position with the camera placed against the posterior thrax (Figure 1). At the initiation of the study, the patient is attached to a spirometer using a mouth piec but continues to breather room air. As thepatient slowly inhales, 30 mCi of ^{133}xenon is administered intravenouly as a bolus. The patient is instructed to hold his breath as an evaluation is made of the distribution of blood flow. The patent then exhales the radioactive gas into the spirometer and rebreathes to equilibrium for the veutilation portion of the study. Oxygen is added to replace the carbon dioxide which is continuously removed during the rebreathing maneuver. This is followed by clearance of the radioactive gas from the patient. Serial scintiphotograms are obtained throughout the entire study. In addition, all data are recorded on magnetic tape for computer analysis. Details of this technique have bedn considered elsewhere (7). This report illustrates the use of this

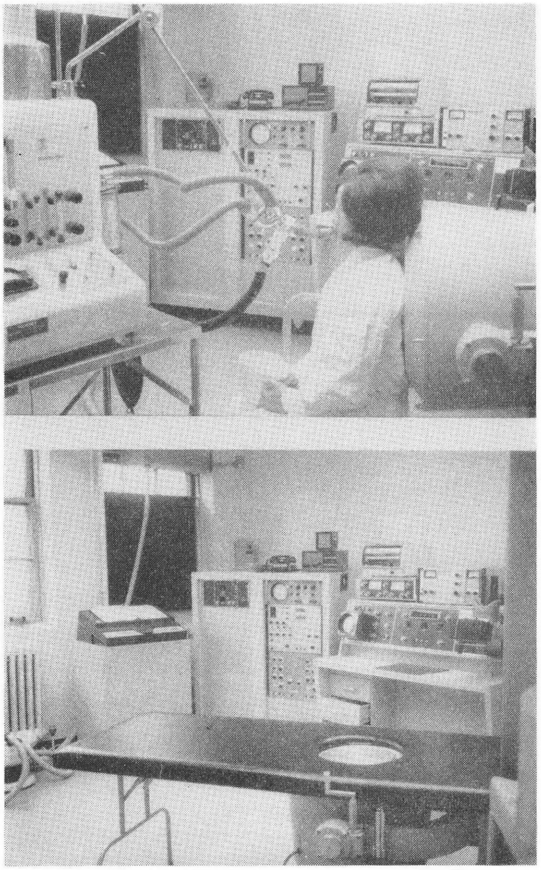

Fig. 1. Arrangement of equipmement used for studyof pulmonary function with patiet either seated or lyingsupine. The scintillation camera is directed toward theposterior thorax.

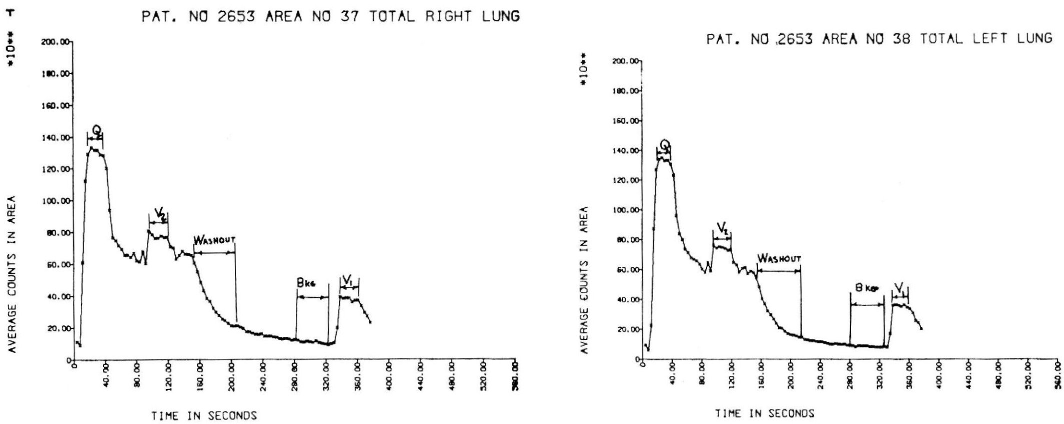

Fig. 2. Calcomp plot of [133]xenon activity in right and left lungs during perfusion and ventilation studies in a patient with normal pulmonary function.

technique for the evaluation of pulmonary function in three patients.

Ressults

Figure 2 shows a plot of the xenon activity in the right and left lungs during perfuusion (8, 9) in a normal subject who was seated for this study with his back to the camera. Q represents the period of breath holding after the intravenous administration of 30mCi of xenon in saline. Data recorded at this time were used to determine regional pulmonary blood flow. V_2 represents lung volume obtained with maximum inspiration after rebreathing xenon to equilibration in both lungs. This was followed by the washout of xenon to background at which time the patient took a finale maximal inspiration (V_1) which was used to determine ventilation indices in selected regions of both lungs. Figure 3 shows selected scintiphotograms obtained during this study. The picture labelled, perf usion (Q)' was obtained during the initial breath holding after the intrvenous administration of the xenon-saline solution and shows the distribution of blood flow whih is seen to decrease gradually as one moves cephlad. This gradient of blood flow is a normal finding in a subject studied in an upright position (8). The second scintiphotogram shown was obtained during deep inspiration following rebreathing of xenon to equilibrium and provides information on lung volume (V_2) which is used to normalize all ventilation and perfusion data. Scintiphotogram #3 was obsained after several minutes of washout and shows nearly a uniform clearance. Sometimelater (approximately 5 minutes) after essentially all xenon had been cleared, the patient took a single deep

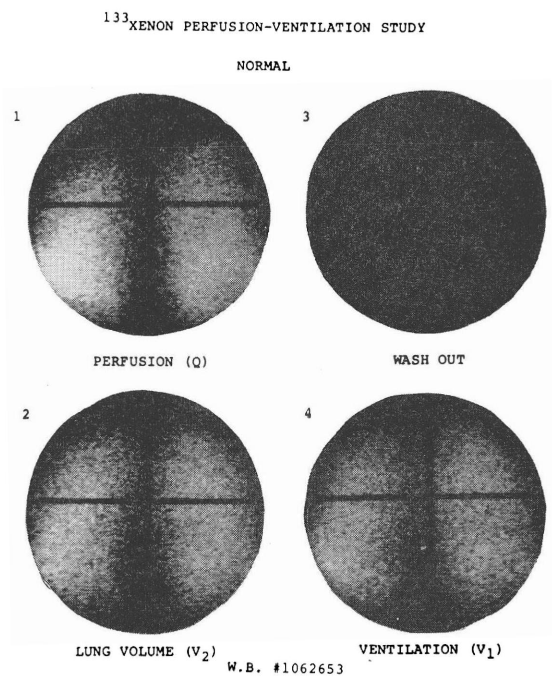

Fig. 3. Selected scintiphotogrms obtained durig perfusion and ventilation studies patient considered inFigure 2..

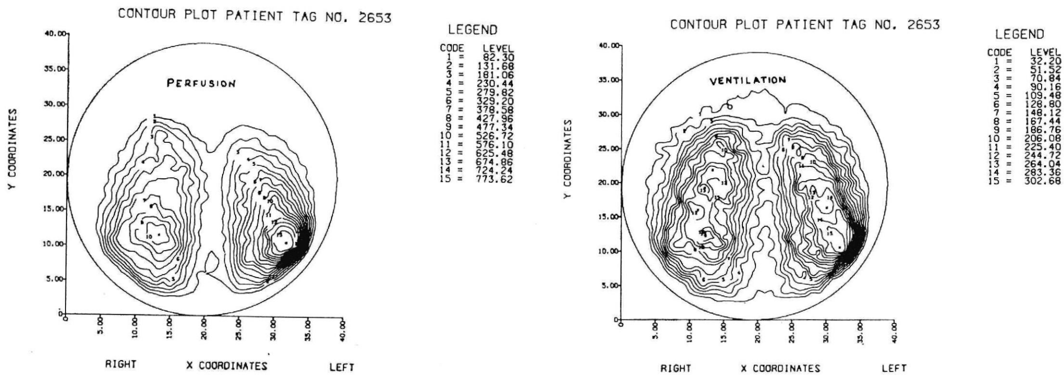

Fig. 4. Calcomp isointensity plots of the distribution of ^{133}xenon buring perfusion evaluation (Q) and during breath holding (V_2) dy patient considered in Figure 2.

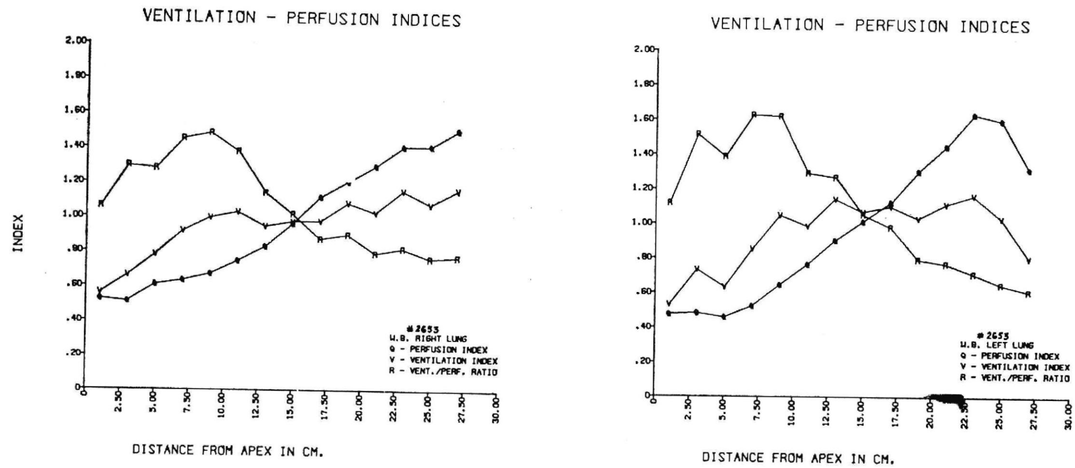

Fig. 5. Calcomp plots of ventilation (V) and perfusion (Q) indices and ventilation-perfusion (V/Q) ratios for right and left lungs of patient considered in Figure 2.

breath of xenon from the spirometer at which time the last picture in this series was obtained. Data obtained during this maneuver are used for determining ventilation indices.

Figure 4 shows to isointensity contonr plots obteined from a Calcomp plotter attached to our computer. The plot on the left shows the distribution of xenon immediately after its intravenous administration of xenon immediately after its intravenous abministration and represents blood flow while that on the right was xenondistribution at the time of maximal inspiration following equilibration of xenon in the lungs. A plot from the computr of ventilation and perfusion indices and ventilation-perfusion ratios for right and left lungs of this patient are shown in Figure 5. The gradual decrease in blood flow and ventilation in the cephalad direction is evideent with this gradient being more pronounced for blood flow than for ventilation. Because of this relationship, the curve representing ventilationperfusion ratio curve has a slope opposite to that of the ventilation and perfusion indices as may be readily appreciated from these graphs.

The second case to de presented relates to a 40-year-old female diebetic who was admitted to the hospital with a chronic couh and icresing dyspnea. A chest roentgenogram showed left lowerlobe infiltrate and pleural effusion. Thoracentesis yielded seo-sanguinous fluid and a clinical diagnosis of pulmonary emboli was made.

Pulmonary function studies showed moderate obstructive lung disease with decreased maximum breathing capacity (59 per cent of predicted value) and timed vital capacity (80 per cent of normal value).

Scintiphotographs during a xenon study (Figure 6) showed a relatively normal pattern of perfusion and ventilation. There was, howeved delay in washout of xenon from the left lung. These findings are much more compatible with the diagnosis of obstructivelung disease than that of pulmonary emboli. Calcomp isointensity plots (Figure 7) revealed asymmetrical perfusion which had not been appreciated on the scntiphotograms. The plots of ventilation and perfusion indices and ventillation ratios (Figure 8) confirmed that there was unevenperfusion and ventilation in the left lung.

The final case is that of a 53-year-old male with a clini᠎ɔal diagnosis of pulmonary embolization who subsequently had pulmonary arteriography-which confirmed the diagnosis of occlusion of the pulmonary artery perfusing the right lower lobe.

A Calcomp isointensity plot (Figure 9) of the distribution of xenon during perfusion and ventilation studies in this patient show essentially normal ventilation but absent perfusion in the right lower lobe, findingstypical of pulmonary embolization (10). This patient was stdied using a high resolution parallel hole collimatorrather than the diverging collimator

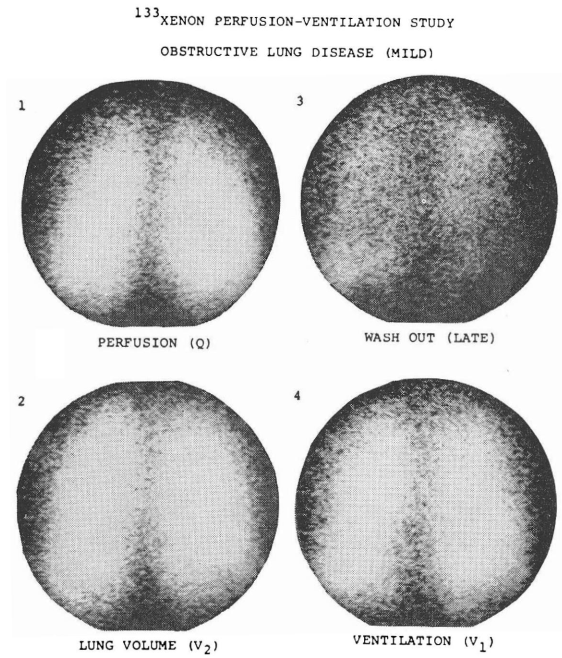

Fig. 6. Selected scintiphotograms obtained during perfusion and ventilation studies in a partient with mild obstructive ıung disease affecting particularly the eft lung.

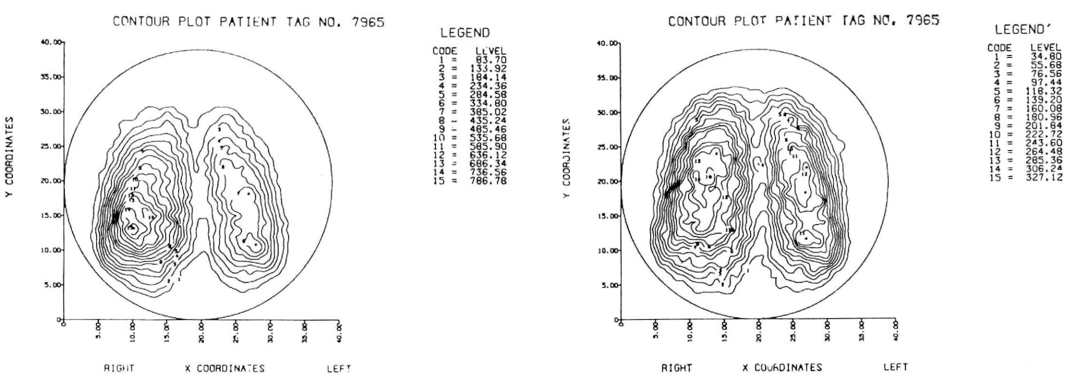

Fig. 7. Calcomp isoinsity plots of the distribution of [133] xenon during perfusion evaluation (Q) and during dreath holding (V_2) by patient considered in Figure 6.

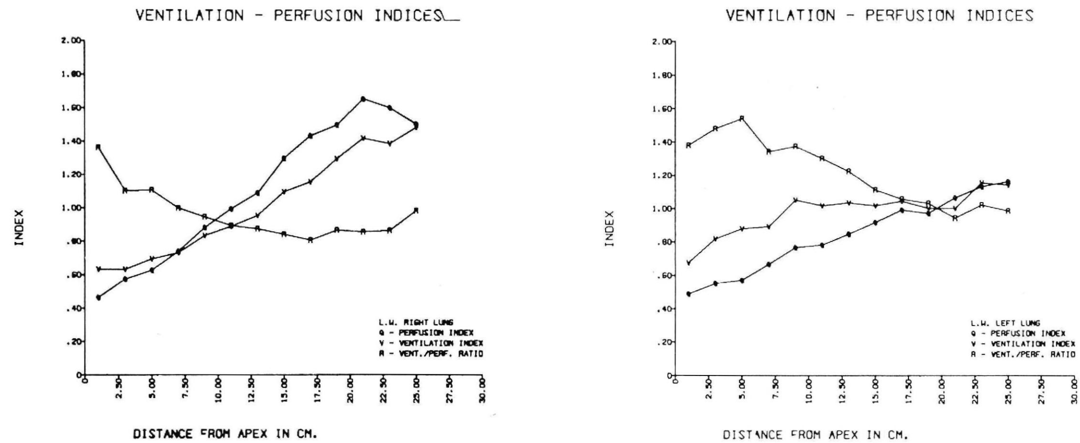

Fig. 8. Calcomp plots of ventilation (V) and perfusion (Q) indices and ventilation-perfusion (V/Q) ratios for right and ieft lungs of patientconsidered in Figure 6.

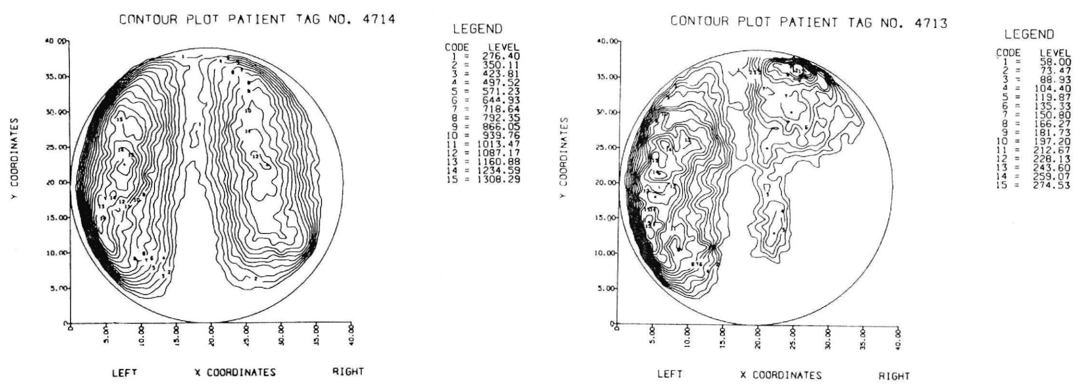

Fig. 9. Calcomp isointensity plots of the distribution of ^{133}xenon durng perfusion and ventilation studies of a patient with a large pulmonary embolus affecting the right lower lobe. This study was performed with a parallel hole collimator which precluded the included the inclusion ff the entire lung fields.

normally employed. As a result, portions of both lungs extend beyond the field of view and therefor not included in the evaluaton.

Summary

Regional pulmonary function evaluation using ^{133}xenon, a scintillation camera and computer has been presented. Thirty mCi of ^{133}xenon in saline solution. The xenonis exhaled into a spirometer after which the patient rebreathes from this system for evaluation of ventilation. Computer programs are written to permit readout of ventilation and perfusion indices, ventilation ratios and isointensity plots of the distribution of xenon during the various phases of each study. Data relating to the study of three patients by this this technique are presented.

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