Roentgenographic Correlation in Pulmonary Venous Hypertension: Prediction of Pulmonary Venous Pressure from Plain Chest Films

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肺静脈圧昂進のレ線学的研究
単純写真所見より肺静脈圧の読影

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肺静脈高圧とそのX線所見に関する研究を確認された68例の僧帽弁膜症について行なつた．研究のためには，胸部の後前方向，側方撮影を行ない，肺静脈基部におけるウエッヂによる平均圧を計測した．単純胸部写真での上葉静脈の読み方の技術が述べられている．

平均肺静脈圧が14㎜水銀柱あるいはそれ以下の患者は正常な肺血管像を呈した．肺静脈圧が15㎜水銀柱を越すと，上葉静脈の拡張が見え始める．Kerley 氏線は平均肺静脈圧が25㎜水銀柱を越えるとみられた．10例は平均肺静脈圧が30㎜水銀柱を越していたが，しかしその全例に肺胞性水腫は見られなかった．これは圧がさらに高まり恐らく40㎜水銀柱以上になるとあらわれるのであろう．

この研究をもとにすると，肺静脈圧の比較的正確な評価が，心臓カテーテルを行なう前にすでに撮影してある胸部写真から予かじめ推測されうる．

放射線家によるこのような観察は異常な心肺血流体力学の程度の評価を可能ならしめ，そして胸部写真の価値を高からしめると考える．

Radiological manifestations of pulmonary venous hypertension are well described in the literature (1, 5, 6, 7, 9, 10, 11, 13, 14 and 15). By means of body-section radiography, angiocardiography and with advanced knowledge in cardiopulmonary physio-pathology, the assessment of roentgen changes in the lung becomes more feasible.

Among radiological findings, dilatation of upper lobe veins and Kerley's lines are the more reliable roentgen signs of pulmonary venous hypertension in mitral heart disease, as well as in numerous other conditions. These are easily identifiable on the plain chest roentgenograms and also show rapid fluctuation with change of pulmonary venous pressures.

The purpose of this study is to correlate these roentgen signs with catheterization data in 68 proven cases of mitral heart disease on the plain chest roentgenograms.

Material and Method

The postero-anterior and left lateral view of plain chest roentgenograms of 68 patients with rheumatic mitral heart disease were studied for the size of upper lobe veins and Kerley's lines. All films were taken within 24 hours of the time of cardiac catheterization in upright position with the film-target distance of 72 inches.

The roentgenograms were initially read without knowledge of catheterization findings. The results were then compared against the mean pulmonary artery wedge pressure which was obtained by the right heart catheterization at rest in supine position. The pulmonary wedge pressure was selected for this study because of its easy accessibility with low morbidity in cardiopulmonary laboratories. The pulmonary wedge pressure also accurately reflects the left atrial pressure as it is practically equal to the pressure in the left atrium (3, 4 and 16). The left atrial pressure is usually synonymous with pulmonary venous pressure except in cases of pulmonary venous stenosis.

All 68 cases, 11 males and 57 females with ages ranging from 19 to 64 years, had proven mitral valvular disease. All patients had right heart catheterization, as well as retrograde left cardiac catheterization via femoral artery. Thirty patients of this group had subsequent corrective cardiac surgery. The valvular lesions in all patients are summarized in Table 1.

Table 1. Summary of Valvular Lesions

Mitral Stenosis	47
Mitral Stenosis and Mitral Insufficiency	13
Mitral Stenosis and Aortic Stenosis	1
Mitral Stenosis and Aortic Insufficiency	4
Mitral Insufficiency	1
Mitral Insufficiency and Aortic Insufficiency	1
Mitral Stenosis, Mitral Insufficiency and Aortic Insufficiency	1
Total Number of Patients	68

1) The Upper Lobe Veins

Pulmonary veins lie inferior and in anterior of the bronchi, while the arteries are generally superior and posterior. The pulmonary artery usually divided into branches corresponding to the division of the bronchi and accompanying the branches of a bronchopulmonary segment. The veins, however, are more semivertical in position and intersegmental in distribution. The upper lobe veins lie more lateral to the corresponding arteries on the posteroanterior chest roentgenogram (Figs. 1A and 2A) and more anteroinferior on the lateral projection (Figs. 1B, 2B and 3). The veins also show narrow angled branching.

In order to investigate the size of upper lobe veins, the diameter of posterior veins and posterior or apical segmental artery of the right upper lobe are compared on the postero-anterior view (Figs. 1A and 2A). The proximal portions of the vessels were measured above the right hilus between the right sixth and eighth posterior rib for the comparison. The posterior vein is usually clearly visible above the hilar shadow on this projection. The posterior segmental artery, however, is occasionally partically superimposed with the vein and the apical segmental artery was used in this case. The left lateral view is also used for the evaluation. The diameter of right anterior vein was compared with the width of right anterior segmental artery. The anterior vein of right upper lobe lies lower and more semivertical position than left on the left lateral view. This is usually well identifiable above or over base of the cardiac shadow in front of vascular hilar shadow on the left lateral projection (Figs. 1B, 2B and 3).

Although there is some variation in the venous pattern in the upper lobe, these variations involve principally interchanges between the posterior and apical veins (2). Therefore, this will not interfer with the evaluation of upper lobe veins.

Fig. 1. B.V. Mitral stenosis with normal vasculature. Mean pulmonary wedge pressure 14 mm. of mercury.

A. Postero-anterior view of right upper lobe showing more lateral location of posterior vein (V-) relative to posterior segmental artery (A-). Note equal size of posterior vein (V-), posterior segmental artery (A-) and apical segmental artery (A_1).

B. Left lateral view showing more antero-inferior and semivertical position of right anterior vein (V_2). Note equal size of right anterior vein (V_2) and right anterior segmental artery (A_2).

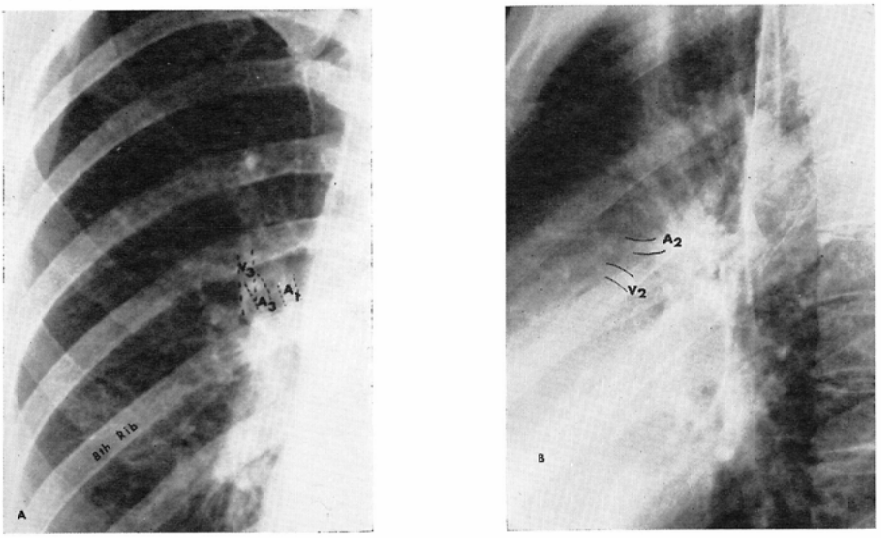


Fig. 2. Laminagram of right upper lobe showing normal vasculature.

A. Frontal laminagram. Note more lateral location of veins relative to the corresponding arteries.

B. Lateral laminagram. Note more anterio-inferior and semivertical to vertical position of veins with narrow angled branching.

A_1=Apical segmental artery. A_2=Anterior segmental artery. A_3=Posterior segmental artery. V_1=Apical vein. V_2=Anterior vein. V_3=Posterior vein. ULA=Upper lobea rtery. ULV=Upper lobe vein.

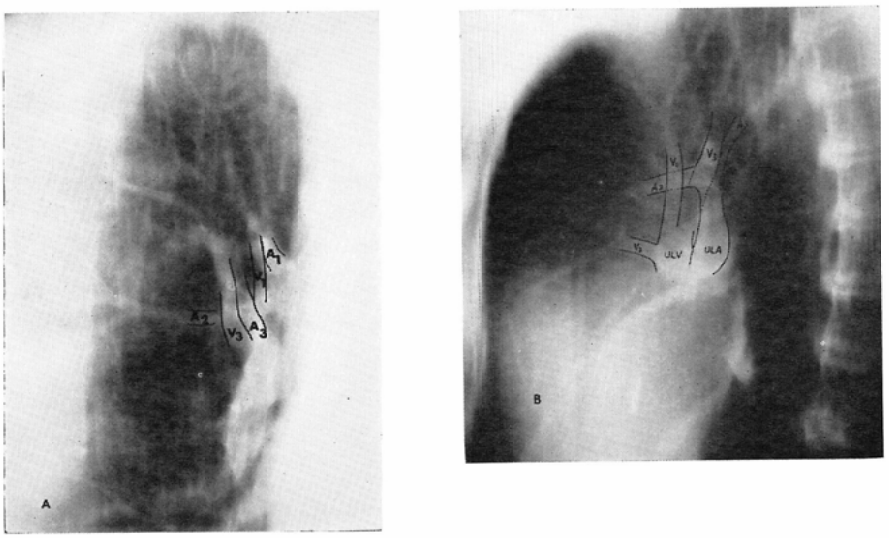
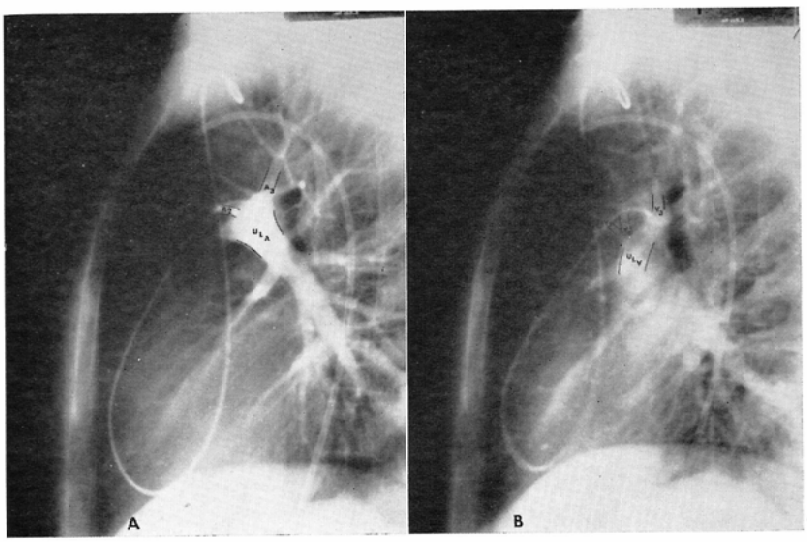
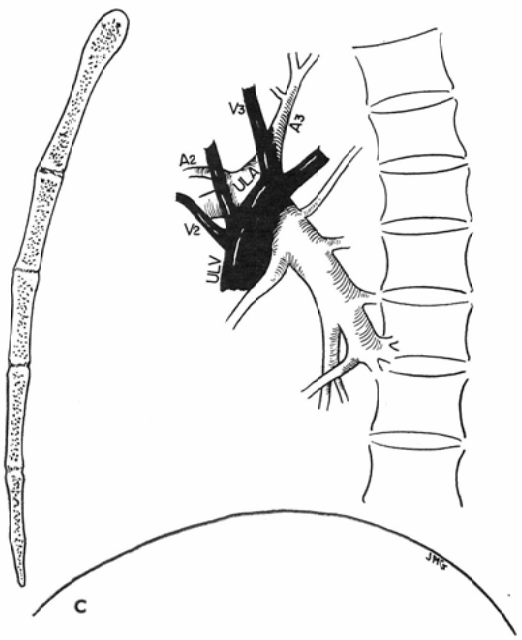


Fig. 3. Normal right lateral pulmonary angiogram showing relative position of right upper lobe veins and arteries.

A. Arterial phase.
B. Venous phase.
C. Composite drawing.
A_2=Anterior segmental artery. A_3=Posterior segmental artery. ULA=Upper lobe artery. V_1=Apical vein. V_2=Anterior vein. V_3=Posterior vein. ULV=Upper lobe vein.





Review of one hundred normal chest roentgenograms showed that the size of upper lobe veins are approximately equal to or less prominent than those of the corresponding arteries. When the diameter of the posterior vein, on the postero-anterior view, or the right anterior vein, on the left lateral projection, are larger than one and one-half times of corresponding arteries, the upper lobe veins are considered to be dilated (Figs. 4 and 5).

Fig. 4. H.R. Mitral stenosis with dilated upper lobe veins. Mean pulmonary wedge pressure 24 mm. of mercury.

A. Postero-anterior view of right upper lobe showing dilated posterior vein (V_3). Diameter of posterior vein (V_3) is about twice of posterior segmental artery (A_3) and apical artery (A_1).

B. Left lateral view showing dilated rigth anterior vein (V_2). Size of right anterior vein (V_2) is about twice of anterior segmental artery (A_2).

C. Lateral laminagram also showing dilated right anterior vein (V_2) and normal size of right anterior segmental artery (A_2).

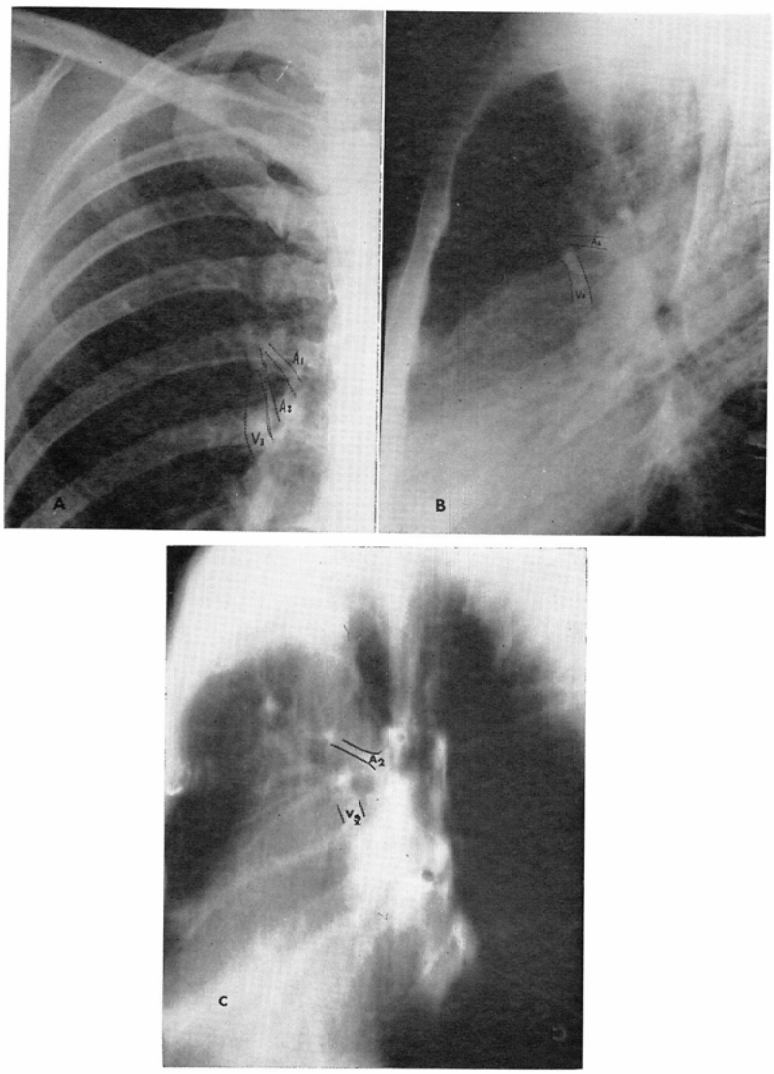
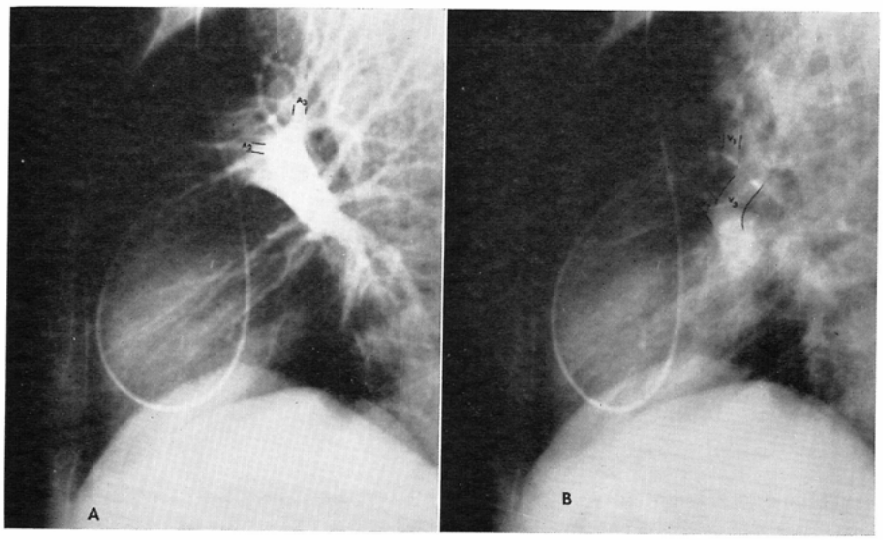


Fig. 5. M.M. Mitral stenosis. Mean pulmonary wedge pressure 28 mm. of mercury. Right lateral pulmonary angiogram showing dilated upper lobe veins. Sizes of veins are about twice of arteries.

A. Arterial phase.

B. Venous phase.

A_2=Anterior segmental artery. A_3=Posterior segmental artery. V_1=Apical vein. V_2=Anterior vein. V_3=Posterior vein.



2) Kerley's Lines

Kerley's lines represent dilated interlobular lymphatics with interstitial edema. They are seen best on the postero-anterior view of chest roentgenogram (Fig. 6). However, the lateral and oblique views are also helpful to recognize the lines.

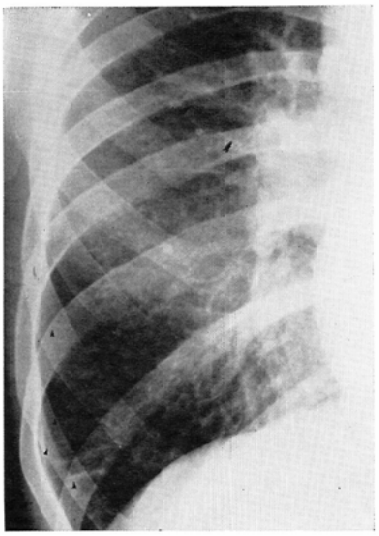
There are three types of Kerley's lines. Kerley's A lines are thin, faint long lines, run obliquely toward the hili and do not follow the course of pulmonary vessels or bronchi. These lines are more central in location and less frequently seen. Kerley's B lines are short, thin transverse lines in the lateral aspect of the lung bases extending to the pleura. The B lines are seen best in the costophrenic angles in stepladderlike pattern. They are more frequently seen than other septal lines and easily recognizable. Kerley's C lines are very fine interlacing lines throughout the lung producing reticular appearance. They are more commonly seen in the lower two-thirds of the lung fields.

The septal lines are also seen in the following disease, other than in the pulmonary venous hypertension and one should make a differential diagnosis: lymphangitic metastases; pneumoconiosis, interstitial fibrosis of the lungs from many causes; primary hemosiderosis; and ligation of the thoracic duct. In all these conditions, however, the lines are of a more permanent nature, while the lines in pulmonary venous hypertension rapidly fluctuate with the pressure changes.

Results and Conclusion

Sixty of 68 patients had elevated mean pulmonary artery wedge pressures ranging from 11 to 38 mm. of mercury. Seven cases had a pressure of 10 mm. of mercury and a pressure of 7 mm. of mercury was found in one patient. Ten mm. of mercury is the accepted upper normal limit of mean wedge pressure

Fig. 6. G.D. Mitral stenosis with Kerley's lines. Mean pulmonary wedge pressure 38 mm. of mercury. Large arrow heads indicating Kerley's A line. small arrow heads are Kerley's B lines. Note dilated upper lobe veins.

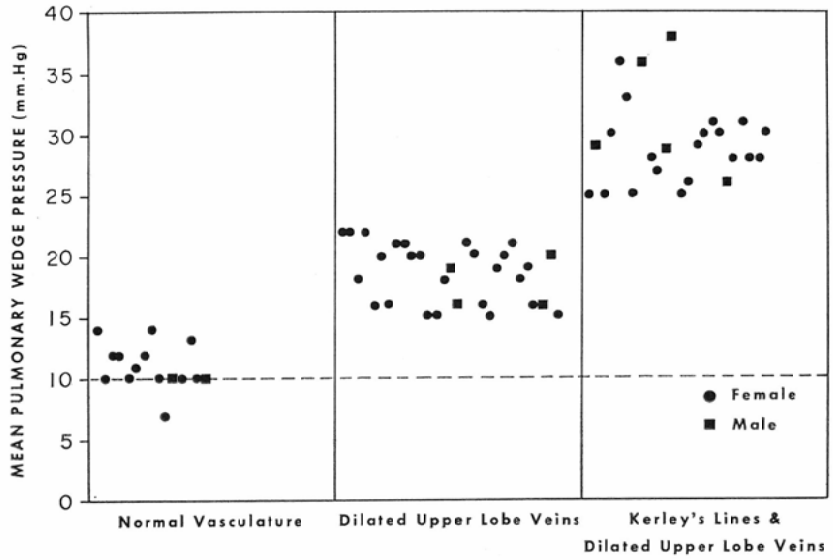


at the Cardiopulmonary Laboratory, West Virginia University Medical Center.

There is good correlation between roentgenographic signs and pulmonary wedge pressures. The results are summarized in Fig. 7

Fifteen patients with the mean pulmonary wedge pressures of 14 mm. of mercury of less showed normal pulmonary vasculature. Fifty-three patients had mean pulmonary wedge pressures above 15 mm. of mer-

Fig. 7. Relationship between mean pulmonary wedge pressure and roentgenographic signs.



cury and all showed dilated upper lobe veins. Kerley's lines were noted on the chest roentgenograms in 24 cases in which mean wedge pressures exceeded 25 mm. of mercury. Patients in this study group did not develop pulmonary alveolar edema during or after cardiac catheterization.

Discussion

Plain chest roentgenograms and mean pulmonary wedge pressures were used in this correlative study.

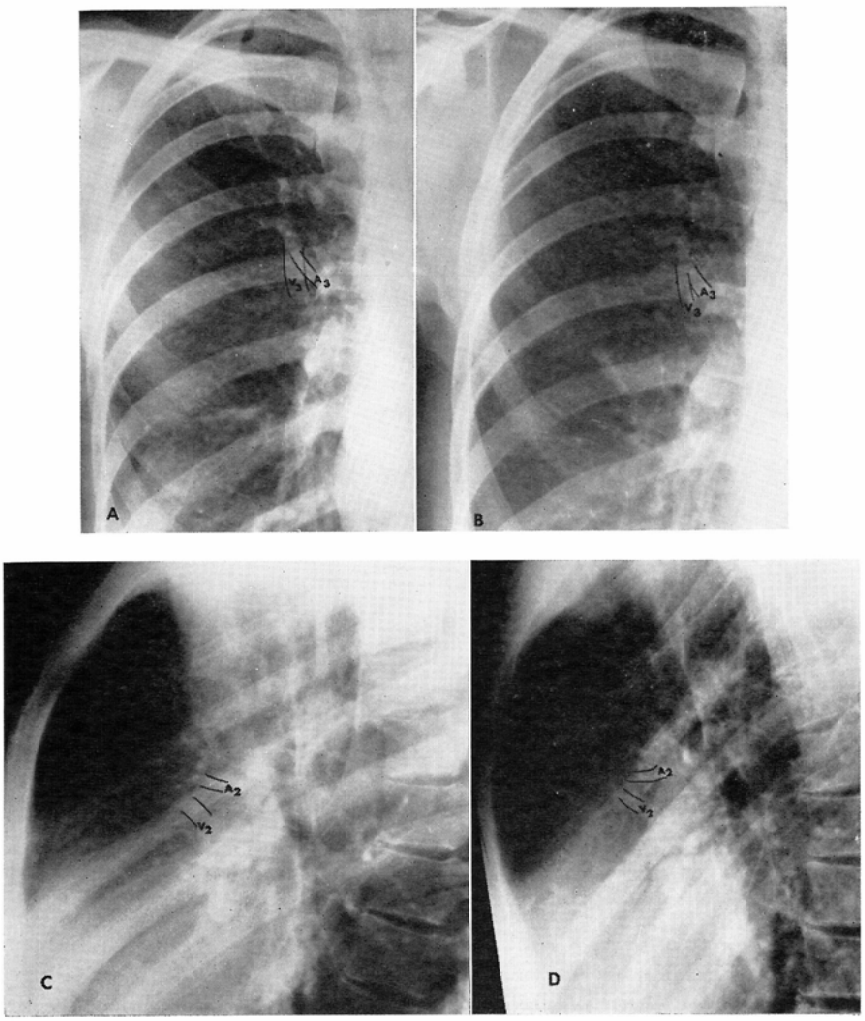
Fig. 8. B.L.A. Mitral stenosis and aortic insufficiency. Mean pulmonary wedge pressure 16 mm. of mercury.

A. Pre-operative P.A. chest showing dilated posterior vein (V_3) of right upper lobe. Size of vein is about twice of posterior segmental artery (A_3).

B. Post-operative P.A. chest now showing normal vasculature. Size of posterior vein (V_3) is now same as posterior segmental artery (A_3).

C. Pre-operative left lateral chest showing dilated right anterior vein (V_2) and normal size of right anterior segmental vein (A_2).

D. Post-operative left lateral chest now showing normal size of both right anterior veins (V_2) and anterior segmental artery (A_2).



They are practical and readily accessible without excessive morbidity. There is good correlation between roentgenographic changes and pulmonary venous pressures and relatively accurate estimation of pulmonary venous pressure can be obtained from the plain chest roentgenogram prior to catheterization. The results of the present study are comparable with the studies by Simon[12] and Lavender, et al.[9].

It is quite possible to identify upper lobe veins on the plain chest film, especially in the right upper lobe. Accuracy in identification will be increased with good knowledge of roentgen anatomy and experience. The lateral view of the chest is as important as the postero-anterior projection, especially in a borderline case. The right anterior vein is usually clearly visible on the left lateral view, especially when pulmonary venous hypertension is present.

Though there is no strict linear relationship between the size of upper lobe veins and severity of pulmonary venous hypertension, kilated upper lobe veins are a good indication of increased pulmonary venous pressure. The size of upper lobe veins are also sensitive to pressure changes and vary promptly (Fig. 8). No attempt was made to grade or establish a comparative ratio between upper and lower venous size.

All patients in this study group with mean pulmonary wedge pressures above 15 mm. of mercury showed dilatation of upper lobe veins. Kerley's lines were demonstrated when the pressure exceeded 25 mm. of mercury. These findings are agreeable with Lavender and his associates[9] and Simon's findings[13]. However, no patient with a pressure above 25 mm. of mercury showed any evidence of decreased upper lobe vein size as described by Simon[12]. This is also agreealb with the finding by Lavender, et al[9].

In 1963, Simon[13] stated that pulmonary alveolar edema appears if the pulmonary venous pressure increases to the order of 30 to 40 mm. of mercury. However, alveolar edema was not noted in 10 cases of this group with wedge pressures over 30 mm. of mercury. The alveolar edema may appear when the pressure is elevated above 40 mm. of mercury, as in Grainger's finding[6].

Summary

Correlative study between roentgenographic changes and pulmonary venous hypertension was made in 68 proven cases of mitral heart disease, by using postero-anterior and left lateral views of plain chest roentgenograms and mean pulmonary wedge pressures. A technique is described for evaluating upper lobe veins on plain chest films.

All patients with the mean pulmonary wedge pressures of 14 mm. of mercury or less showed normal pulmonary vasculature. Dilatation of upper lobe veins begun to appear when the mean pulmonary wedge pressure exceeded 15 mm. of mercury. Kerley's lines were seen on chest films when the mean pressure was elevated over 25 mm. of mercury. Ten patients had the mean sedge pressure over 30 mm . of mercury and all failed to show alveolar edema. This may appear with further elevation of the pressure, possibly over 40 mm. of mercury.

On the basis of this study a relatively accurate estimate of pulmonary venous pressure can be predicted from the plain chest roentgenogram prior to cardiac catheterization. Such observation by the radiologist allows estimation of degree of abnormal cardiopulmonary hemodynamics, thereby enhancing the value of the chest roentgenogram.

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