Costophrenic Septal Lines in Pulmonary Venous Hypertension

By André J. Bruwer, M.B., Ch.B., F. Henry Ellis, Jr., M.D. and John W. Kirklin, M.D.

On the thoracic roentgenograms of patients with mitral stenosis, costophrenic septal lines are frequently seen. These lines are a sign of pulmonary venous hypertension. They were not seen in a representative group of patients with pulmonary arterial hypertension but without pulmonary venous hypertension.

Progress in the surgical management of congenital and acquired cardiovascular diseases has stimulated many branches of medicine. Roentgenology of the cardiovascular system is one of the diagnostic fields that has profited by these advances. One of the interesting and curious findings in roentgenograms of the thorax of patients with mitral heart disease has been the presence of fine, short, straight linear densities in the costophrenic regions (figs. 1 and 2). Although these lines are not specific for mitral heart disease, their preponderant presence in this condition stimulated us to review the roentgenograms at the Mayo Clinic of 152 surgical cases of mitral stenosis.

Definition

The lines with which this paper deals have been variously described as “lines B of Kerley,”1 “horizontal lines,”2 “linear x-ray shadows”3 and “septal lines.”4 They are reported to occur occasionally in association with a number of conditions including acute and chronic pulmonary congestion, severe mitral stenosis,5 pulmonary hemosiderosis in the absence of congestion,6 pneumoconiosis, diffuse pulmonary fibrosis and lymphogenous pulmonary metastasis. The lines usually are seen best in the costophrenic angles and better on the right side than on the left. The posteroanterior view is the best, but occasionally an oblique or lateral view will show them to advantage. They run perpendicular to the pleural surface. As a rule, a single line will be of the same thickness throughout, but if it tapers, its broadest end tends to be based on the visceral pleura. The lines vary in number from 2 or 3 to 10 or 15. They extend from 2 to 4 inches upward from the costophrenic angle and vary in thickness from a hairline to 2 mm. in diameter. Often they are spaced from 0.5 to 1 cm. apart. They may remain unchanged after mitral commissurotomy, or they may disappear. Sometimes they disappear as early as the first day after mitral commissurotomy.

Cautious interpretation of these lines is advisable, so that they will not be confused with linear fibrosis following inflammatory processes or with peripheral arborization of the pulmonary vascular tree (fig. 3).

Pathogenesis

Some authors have related these lines to “pulmonary hypertension in patients with mitral stenosis,”7 while others have considered them as “radiological signs in pulmonary hypertension.”8 The latter authors have stated that “in general, the lines are present only when there is at least moderate pulmonary hypertension.”9

Fleischner and Reiner,3 basing their interpretations on Gough and Wentworth’s method9 of holoptic microtome sections of lungs, present evidence that the lines are sometimes due to peripheral interlobular septa which have been rendered visible on roentgenograms, after hemosiderin has been deposited in or adjacent to them. Such lines tend to be relatively permanent. Similar, but transient, lines are thought to be due to linear accumulations of fluid on the septa, appearing during periods of pulmonary congestion and disappearing as
pulmonary congestion is overcome. Kerley\textsuperscript{7} considered the lines to be due to engorged subpleural lymphatics.

**Present Study**

We have examined roentgenograms of 152 cases of mitral stenosis in which the patients had undergone mitral commissurotomy. The study was made specifically for the presence of costophrenic septal lines. As in the study by Carmichael and associates,\textsuperscript{5} doubtful cases were regarded as negative. In 51 of the 152 cases of mitral stenosis, the lines were present. In view of work, previously referred to, relating the lines to pulmonary hypertension, our patients having mitral stenosis who had undergone cardiac catheterization were analyzed in regard to the presence or absence of lines. Furthermore, roentgenograms in 65 cases of pulmonary hypertension due to causes other than mitral stenosis were examined for the presence of costophrenic septal lines. We were impressed with the fact that the costophrenic septal lines frequently disappeared soon after mitral commissurotomy, whereas in other cases they remained unchanged after mitral commissurotomy. Cases in which a follow-up study of at least six months was made were therefore analyzed in an attempt to relate disappearance of the lines to prognosis.

**Relation of Mean Pulmonary-Trunk Pressures to Costophrenic Septal Lines**

In 46 of our cases of mitral stenosis, mean values for pulmonary-trunk pressures were available. We arbitrarily divided our cases into the group with mean pressures below
60 mm. Hg and those with mean pressures above 60 mm. Hg. It was found that 14 of the 46 patients had mean pressures of more than 60 mm. Hg; of the 14, 8 had costophrenic septal lines, whereas 6 did not. Thirty-two of the 46 patients had mean pulmonary-trunk pressures of less than 60 mm. Hg; 12 had lines, whereas 20 did not show lines (table 1). Our findings contrast with those of Carmichael and associates, who noted lines in 100 per cent (18 cases) of their patients having mean pressures of more than 60 mm. Hg and in only 18 per cent (five cases) of those having mean pulmonary-trunk pressures of less than 60 mm. Hg.

**PULMONARY-ARTERY SYSTOLIC PRESSURE AND COSTOPHRENIC SEPTAL LINES**

Whitaker and Lodge\(^2\) found that costophrenic septal lines were present in 6 of 8 patients having severe pulmonary hypertension, in 8 of 10 patients having moderate pulmonary hypertension and in 1 of 7 patients having mild pulmonary hypertension. In order to compare our cases with their group, we arbitrarily divided our cases into mild, moderate and severe pulmonary hypertension when the systolic pressures in the pulmonary trunk were respectively 30 to 49 mm. Hg, 50 to 69 mm. Hg and 70 mm. Hg or more. Of the 10 patients having mild pulmonary hypertension, two had lines; of 13 having moderate pulmonary hypertension, 7 had lines; while of 29 having severe pulmonary hypertension, 17 had lines (table 2).

**RELATION OF MEAN WEDGE PRESSURES TO COSTOPHRENIC SEPTAL LINES**

We were able to obtain figures for mean wedge pressures in 38 cases to compare with the group of 28 cases of mean wedge pressures presented by Carmichael and co-workers. Here again, they found a closer relation between the height of the mean wedge pressure and the presence of lines (table 3). In our group there was no correlation between the height of the mean wedge pressure and the distinctness, number or size of the lines. In fact, we had graded the lines as “marked” in only three of 38 cases, and in all three the mean wedge pressures were less than the arbitrary dividing line of 29 mm. Hg. The mean wedge pressures in these three cases were 24, 25 and 28 mm. Hg, respectively.

**RELATION OF POSTCOMMISSUROTOMY STATUS TO COSTOPHRENIC SEPTAL LINES**

An attempt was made to correlate the status of the lines with the clinical result six months or more after surgical intervention. All nine patients in whom lines disappeared after operation had results graded as “excellent.” Seven of 11 patients in whom the lines had persisted after operation had excellent results; two had died and two were

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**Table 1.—Relationship of Mean Pulmonary Trunk Pressures to Presence of Costophrenic Septal Lines on Roentgenograms of the Thorax**

<table>
<thead>
<tr>
<th>Mean Pulmonary-Trunk Pressures</th>
<th>Lines Present</th>
<th>Lines Absent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cases</td>
<td>%</td>
<td>Cases</td>
</tr>
<tr>
<td>More than 60 mm. Hg...</td>
<td>8</td>
<td>57</td>
</tr>
<tr>
<td>Less than 60 mm. Hg...</td>
<td>12</td>
<td>37</td>
</tr>
</tbody>
</table>

**Table 2.—Relationship of Degree of Pulmonary Hypertension to Presence of Costophrenic Septal Lines on Roentgenograms of the Thorax**

<table>
<thead>
<tr>
<th>Pulmonary Hypertension, Degree</th>
<th>Costophrenic Septal Lines</th>
<th>Absent, cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present, cases</td>
<td>Absent, cases</td>
<td></td>
</tr>
<tr>
<td>Mild, 30–49 mm. Hg</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>Moderate, 50–69 mm. Hg</td>
<td>7</td>
<td>6</td>
</tr>
<tr>
<td>Severe, more than 70 mm. Hg</td>
<td>17</td>
<td>12</td>
</tr>
</tbody>
</table>

**Table 3.—Relationship of Mean Pulmonary Wedge Pressures to Presence of Costophrenic Septal Lines on Roentgenograms of Thorax**

<table>
<thead>
<tr>
<th>Mean Wedge Pressures</th>
<th>Costophrenic Septal Lines</th>
<th>Absent, per cent of cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Present, per cent of cases</td>
<td>Series of Carmichael and associates(^5)</td>
<td>Series of Carmichael and associates(^5)</td>
</tr>
<tr>
<td>Mayo Clinic series</td>
<td>Mayo Clinic series</td>
<td></td>
</tr>
<tr>
<td>29 mm. Hg. and over</td>
<td>55</td>
<td>86</td>
</tr>
<tr>
<td>Less than 29 mm. Hg*</td>
<td>50</td>
<td>7.5</td>
</tr>
</tbody>
</table>

* The figure, 29 mm. Hg., was arbitrarily chosen for convenience of comparison. In all our cases the mean wedge pressures were considered to be elevated.
TABLE 4.—Pulmonary Hypertension in Conditions Other Than Mitral Stenosis

<table>
<thead>
<tr>
<th>Defect</th>
<th>Cases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ventricular s.d.</td>
<td>22</td>
</tr>
<tr>
<td>Ventricular s.d. and atrial s.d.</td>
<td>1</td>
</tr>
<tr>
<td>Atrial s.d.</td>
<td>15</td>
</tr>
<tr>
<td>A.V. commune</td>
<td>1</td>
</tr>
<tr>
<td>P.D.A.</td>
<td>14</td>
</tr>
<tr>
<td>P.D.A. and atrial s.d.</td>
<td>2</td>
</tr>
<tr>
<td>Idiopath. pulmon. hypertens.</td>
<td>8</td>
</tr>
<tr>
<td>Pulmonary fibrosis</td>
<td>1</td>
</tr>
<tr>
<td>Pericarditis</td>
<td>1</td>
</tr>
<tr>
<td>Total</td>
<td>65</td>
</tr>
</tbody>
</table>

* Pulmonary arterial hypertension had been proved by cardiac catheterization but pulmonary venous hypertension was not a characteristic feature. In none of these cases were costophrenic septal lines seen on roentgenograms of the thorax.

s.d. = septal defect.
A.V. = atrioventricularis.
P.D.A. = patent ductus arteriosus.

regarded as failures. If any judgment can be made on such a small group, it would be to suggest that among those patients who had costophrenic septal lines which disappeared after operation, the prognosis would appear to be excellent.

Of further interest in regard to the patients who had died in the first year after operation was the finding that death seemed to be more likely in the group in which we had categorized the lines as being “marked” before operation than in the group in which they had been graded as “slight.” Many more cases will have to be studied, however, before any valid conclusions can be drawn.

PULMONARY HYPERTENSION IN CONDITIONS OTHER THAN MITRAL HEART DISEASE

As has been stated before, we found that a third of our patients who underwent operation for mitral stenosis had costophrenic septal lines. In order to determine whether the lines are related to conditions in which pulmonary venous hypertension is a characteristic feature, rather than to conditions in which pulmonary arterial hypertension occurs without necessarily being associated with pulmonary venous hypertension, we examined the roentgenograms of 65 patients in the latter category. None of the roentgenograms of these patients showed septal lines (table 4).

In addition, the roentgenograms of 20 patients who had emphysema complicated by cor pulmonale, pulmonary hypertension undoubtedly being present, were examined. Not one of the roentgenograms of these patients showed evidence of costophrenic septal lines.

Furthermore, the roentgenograms of 25 patients who had died and who had had calcific aortic stenosis were examined and costophrenic lines were found in those of three; these three patients had had evidence of cardiac failure with an elevated pulmonary venous pressure.

It would appear that these lines occur, for practical purposes, only among patients having pulmonary venous hypertension associated with pulmonary arterial hypertension, and particularly in mitral heart disease, but not in pulmonary hypertension confined to the pulmonary arterial side.

COMMENT

We found costophrenic septal lines in the thoracic roentgenograms of a third of 132 cases of mitral stenosis. The roentgenograms were taken prior to the patient’s operation in each case. Other authors have described these lines in even a higher percentage of cases than we found. The finding of costophrenic septal lines on a roentgenogram becomes, therefore, a valuable roentgenologic sign. Furthermore, in our experience, the only other condition in which these lines have been seen with significant frequency has been in cardiac failure with disease of the aortic valve and evidence of raised pulmonary venous pressure. Contrary to the impression given in the literature, we do not believe that costophrenic septal lines are a sign of pulmonary arterial hypertension. In the examination of roentgenograms of the thorax of 65 patients with pulmonary arterial hypertension (in cases of, for instance, ventricular septal defect, atrial septal defect and others listed in table 4) and 20 patients with cor pulmonale, following emphysema, we did not find examples of costophrenic septal lines.
It is our opinion, therefore, that these lines are more specifically related to pulmonary hypertension involving the pulmonary venous as well as the pulmonary arterial circulation. We did not, however, find a striking correlation between the degree of elevation of pulmonary wedge pressures and the presence of costophrenic septal lines.

If the distended lines of the type that disappear after operation are assumed to be distended lymphatics, as Kerley suggested, the description of the lymphatic drainage of the lung, as presented by Miller, becomes of interest. According to Miller the pulmonary parenchymal lymphatics drain along the pulmonary veins to the hilus of the lung, and from there they drain to the hilar lymph trunks and nodes. The pleural and subpleural lymphatics run in the numerous sublobular septa, and drain over the surface of the lungs to the hilum. One may speculate, therefore, that when the pressure of blood in the pulmonary venous system rises, this interferes with the drainage of the perivenuous lymphatics, their tendency then being to drain peripherally and then via the pleural lymphatic route to the hilum. If they become distended enough they may become visible on the roentgenogram.

An alternative, or perhaps an additional, explanation for the prominence of lymphatics in pulmonary venous obstruction, is found in the experiments of Warren and Drinker on dogs. They discovered a greatly increased flow of lymph from cannulated lymphatics of the lung of the dog after mechanical obstruction of the pulmonary veins. They postulated that the increased flow of lymph was due to a combination of pulmonary hypertension and anoxemia causing greater capillary permeability.

Why costophrenic septal lines would be seen best in the lower 3 or 4 inches of the lung is difficult to explain, except that there may be a hydrostatic effect, the portions of the lung that are dependent most of the time being affected the earliest and the most. Furthermore, the suggestion has been made that the lower portions of the lung fields are better supplied with lymphatics than the upper portions.

This theory would explain also why septal lines do not develop among patients with pulmonary arterial hypertension but without pulmonary venous hypertension. Pulmonary lymphatics drain along the veins but not along the pulmonary arteries and, therefore, their central drainage is not interfered with when the pressure rises only on the arterial side. Lymphatic cannulation experiments in induced pulmonary arterial hypertension would be of great interest.

In a small group of patients in whom we correlated the clinical result six months after operation with the disappearance or persistence of lines after operation, it appeared that surgical results were more consistently excellent in the cases in which the lines disappeared than in the cases in which the lines remained. It is possible that the disappearance of lines reflects a lesser degree of pulmonary damage than exists in the patients in whom the lines remain. As has been mentioned before, there is evidence that the permanent lines probably are associated with hemosiderosis.

**SUMMARY AND CONCLUSIONS**

We have found costophrenic septal lines a valuable roentgenologic sign of pulmonary venous hypertension. The lines occurred in a third of surgical cases of mitral stenosis at the Mayo Clinic, but we failed to see them in any cases in which pulmonary arterial hypertension originated proximal to the pulmonary capillary bed and in which pulmonary venous hypertension was, therefore, not a characteristic feature.

Although the lines may occur in association with other conditions, the disease with which they are primarily associated is mitral stenosis.

**SUMMARIO IN INTERLINGUA**

Le roentgenogramma thoracìe de patientes con stenosis mitral exhibi frequentemente lineas septal costophrenic. Iste lineas es un signo de hypertension pulmono-venose. Illos non eseva trovate in un gruppo representative de patientes con hypertension pulmono-arterial sed sin hypertension pulmono-venose.
REFERENCES


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Circulation. 1955;12:807-812
doi: 10.1161/01.CIR.12.5.807

Circulation is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
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Print ISSN: 0009-7322. Online ISSN: 1524-4539

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