Cor Pulmonale
A Consideration of Clinical and Autopsy Findings*

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Chronic cor pulmonale may be defined as hypertrophy of the right ventricle initiated by pulmonary hypertension. This follows increased resistance to blood flow within the lesser circulation as a result of parenchymal pulmonary disease, primary pulmonary arteriolar disease, or marked deformity of the thoracic cage. The existence of such heart disease may be recognized clinically in the presence of signs of failure of the right ventricle, or in the absence of frank failure by a combination of history, physical findings, x-ray and electrocardiographic evidence. Post mortem examination reveals right ventricular hypertrophy in a certain percentage of patients in whom clinical diagnosis has not been established.

In 1783, Senac remarked on cardiac enlargement in asthmatics. Louis, in 1830, stated that enlargement of the heart occurred in all of the cases he had seen die of emphysema who also had edema. Budd, in 1840, stressed the reduction in capillary circulation of the lungs in emphysema leading to obstruction of circulation through the pulmonary arteries, and finally to dilatation of the right heart and edema "so frequently met with in emphysematous persons". Laennec mentioned hypertrophy and dilatation of the heart and dilatation of the pulmonary artery as a sequel to emphysema. Sibson, in 1848, described autopsies on patients with emphysema dying in congestive failure with marked hypertrophy of the right ventricle. In the 1920's and 1930's there was considerable controversy about the frequency and the pathogenesis of cor pulmonale. White and Brenner in 1933, remarked on the rarity of cor pulmonale. At present exact figures of the incidence of chronic cor pulmonale are lacking, but Sprague remarks on its relative infrequency in the United States. He quotes the findings of White and Jones who reported in 1928 an incidence of 0.9 per cent in a series of 2,314 cases of organic heart disease in New England, and a report by White of 25 well marked cases of chronic cor pulmonale in 4,000 post mortem examinations at the Massachusetts General Hospital from 1932 to 1942.

Several articles reveal widely varying figures on the incidence of cor pulmonale, and as might be expected a quite high percentage is reported where the work is based on post mortem findings in patients with long standing severe pulmonary disease. Griggs, Coggin and Evans, in a study of cor pulmonale in 1937, reviewing autopsy protocols of 18,000 consecutive autopsies, found the highest incidence of right ventricular hypertrophy in silicosis. Fifty-two per cent of 24 patients with silicosis showed right ventricular hypertrophy, with failure in 50 per cent. In 45 cases of pure

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emphysema, right ventricular hypertrophy was found in 28.9 per cent, with failure in 22 per cent. The hearts of patients with pulmonary tuberculosis showed right ventricular hypertrophy in 3.7 per cent, with definite failure in 1.8 per cent of the 1,470 cases. In 41 cases of tuberculosis with associated pulmonary lesions, particularly pneumonoconiosis, 36.6 per cent had right ventricular hypertrophy. Nemet and Rosenblatt, in 1937, found exclusive hypertrophy of the right ventricle in 34 per cent of 71 cases of pulmonary tuberculosis. Kountz, Alexander and Prinzmetal, in 1936, who separated and weighed the right and left ventricles of 17 patients with marked emphysema, found hypertrophy of the right ventricle in 10 of 17 cases, with hypertrophy of both right and left ventricle in most of these cases. Scott and Garvin, in 1941, reviewed a series of 6,548 autopsies at the Cleveland City Hospital to determine the incidence of primary right heart hypertrophy (excluding congenital defects and regardless of the presence or absence of failure, using the thickness of the right ventricle as a criterion). In this series there were 790 who died of heart disease, of which 50, or 6.3 per cent, seemed to be cor pulmonale. Spain and Handler reviewed 60 cases of cor pulmonale. In their series the leading etiologic factor was tuberculosis, followed by asthma, bronchiectasis and emphysema. A fairly large number, nine of the 60, had primary pulmonary arteriolar sclerosis. The figures on incidence of cor pulmonale in tuberculosis vary from approximately 4 to 40 per cent. Higgins reported that about 30 per cent of all tuberculosis patients coming to autopsy at the Green Lake Sanitarium showed evidence of right heart failure.

The author's experience indicates that chronic cor pulmonale is a frequent and often overlooked form of heart disease. A large percentage of our medical patients are sent to Arizona for climatic relief of respiratory disease. These patients have generally experienced progressive shortness of breath with onset in the late 40's or early 50's with usually no prior history of asthma, pulmonary infection, or occupational exposure to dusts. The chief abnormal physical finding is marked emphysema. After two or three years of progressive dyspnea despite medical treatment they are either sent or come of their own volition to Arizona for climatic relief. In these patients, as well as in our tuberculous patients, cor pulmonale is a prominent feature.

From November 5, 1948, to October 29, 1951, a total of 174 autopsies were performed. In 106 of these a significant degree of cardiac abnormality was found, but not all of them had been diagnosed clinically as having heart disease. Of the 106 patients with heart disease 54 or slightly over 50 per cent were considered to have cor pulmonale from the criteria mentioned below. The most common cardiac abnormalities at post mortem, aside from cor pulmonale, were those secondary to arteriosclerosis and hypertension.

The pathological diagnosis of cor pulmonale was based on the presence of right ventricular hypertrophy, the absence of significant intrinsic cardiac disease, and the presence of sufficient pulmonary disease to act as an etiological factor. Right ventricular thickness of 5 mm. or over was regarded
as evidence of right ventricular hypertrophy. In two cases a right ventricle which measured 4 mm. in thickness was regarded as hypertrophied. In these cases the left ventricle was only 10 mm. in thickness. Hypertrophy of the papillary muscles and trabeculae carnae of the right ventricle was regarded as significant in determining abnormal degrees of right ventricular hypertrophy. Patients with hypertrophied right ventricles who also had coronary disease, or systemic hypertension with left ventricular hypertrophy, were not regarded as having cor pulmonale. Thickness of the right ventricle in this series with cor pulmonale varied from 4 to 15 mm., and the thickness of the left ventricle from 10 to 20 mm. In one a 20 mm. left ventricular thickness was associated with a 10 mm. thickness of the right ventricle. The thickest right ventricle, 15 mm., was associated with a left ventricular thickness of 18 mm. The average thickness of the right ventricle was 7.3 mm., and the average thickness of the left ventricle was 14.4 mm. The heart weight varied from 260 to 510 grams. Most of the hearts were over 400 grams in weight. In patients with arteriosclerotic and hypertensive heart disease, despite marked thickness of the left ventricle, the right ventricle was not proportionately increased in thickness. Thus, for example, a 23 mm. left ventricular thickness might be associated with a right ventricular thickness of 6 or 7 mm. The state of the heart at the time of death, whether in systole or diastole and the amount of cardiac dilatation, makes a considerable difference in the measured thickness of the ventricle. The point of measurement also makes considerable difference.

Several studies of cor pulmonale have been carried out by investigators who weighed the left and right ventricles separately. Numerous authors have remarked on the fairly consistent presence of left ventricular hypertrophy in cor pulmonale and have given various explanations for this finding. The explanation of Parkinson and Hoyle is that the left ventricular hypertrophy is due to coincidental hypertension. This does not explain the finding in any of our cases, as none of them had a significant degree of systemic hypertension. Other explanations of the presence of left ventricular hypertrophy include anoxia as the significant mechanism causing left ventricular hypertrophy, and the explanation of Scott and Garvin that the arrangement of muscle fibers of the right and left ventricles are such that hypertrophy of one ventricle necessitates a concomitant hypertrophy of the other.

Table I itemizes some of the data from our post mortem statistics. Slightly over 50 per cent of our patients with pulmonary tuberculosis and with other chronic pulmonary disease (chiefly emphysema) were found to have cor pulmonale. It should be noted that over 90 per cent of our deaths were autopsied during the period covered by this report. In this series of patients where pulmonary emphysema seemed to be more marked than the amount of tuberculosis, the case is included as other pulmonary disease rather than tuberculosis. It should be noted that all of the tuberculous patients with cor pulmonale had considerable emphysema. With the exception of four tuberculous patients who died following surgery or pulmonary hemorrhage, all of the tuberculous patients with cor pulmonale...
died of pulmonary insufficiency or a combination of cardio-pulmonary insufficiency. Two with emphysema and cor pulmonale died of hemorrhage from gastric ulcers, and one died following surgery for traumatic intra-abdominal injuries. All of the remainder died of pulmonary insufficiency or a combination of cardio-pulmonary insufficiency. Only 13 of the 54 who showed definite right ventricular hypertrophy at autopsy were noted as being in clinical failure before death. The presence of cardiac failure could not be definitely equated with the amount of right ventricular hypertrophy, a finding analogous to that seen in systemic hypertension.

Of the 54 found to have chronic cor pulmonale at autopsy, a clinical diagnosis of cor pulmonale was made in only 21, and of the group of 54 only 13 were in clinical cardiac failure before death.

TABLE I: POSTMORTEM INCIDENCE OF COR PULMONALE AND ETIOLOGICAL FACTORS CONCERNED
Whipple VAC, November 5, 1948, to October 29, 1951

<table>
<thead>
<tr>
<th></th>
<th>Number Autopsied</th>
<th>Pct. of Pct. of Pct. of Total Cor Pulm.</th>
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</thead>
<tbody>
<tr>
<td>All autopsies</td>
<td>174</td>
<td>100</td>
</tr>
<tr>
<td>Number with heart disease</td>
<td>106</td>
<td>61</td>
</tr>
<tr>
<td>Number with cor pulmonale</td>
<td>54</td>
<td>31</td>
</tr>
<tr>
<td>Number with pulmonary tuberc.</td>
<td>62</td>
<td>36</td>
</tr>
<tr>
<td>Tuberc. cases with cor pulmonale</td>
<td>32</td>
<td>18</td>
</tr>
<tr>
<td>Pulmonary diseases not tuberc.</td>
<td>41</td>
<td>24</td>
</tr>
<tr>
<td>(Chiefly emphysema)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Non-tuberc. with cor pulmonale</td>
<td>22</td>
<td>13</td>
</tr>
<tr>
<td>Clinical diagnosis of cor pulmonale</td>
<td>21</td>
<td>12</td>
</tr>
<tr>
<td>Cor pulmonale patients in clinical cardiac failure</td>
<td>13</td>
<td>7</td>
</tr>
</tbody>
</table>

In the patient with obvious right heart failure with edema, distended neck veins, ascites, hepatomegaly and cyanosis, the diagnosis of cor pulmonale may be made readily. The diagnosis of enlargement of the right heart prior to the onset of failure is important from the standpoint of therapy and prognosis and it is a diagnosis not too readily made. Physical examination alone usually is of limited value. In the absence of failure the heart size is likely to be normal, and enlargement of the various portions of the heart cannot be determined by physical examination in the patient with severe chronic pulmonary disease. The presence of an accentuated pulmonary second sound and a forceful sub-xiphoid pulse should be viewed with suspicion. In many cases the heart sounds are so muffled by emphysema as to be inaudible except in the sub-xiphoid region. In the absence of cardiac failure circulation time is normal. The cardiac rhythm is usually normal whether the patient is in failure or not. In only one of the cases in this series was there an abnormal rhythm, an auricular flutter in a case with cor pulmonale and tuberculous pericarditis in failure. In this
patient a catheter had been placed in the pericardial cavity believing it to be the pleural cavity, and lavage with azo-chloramide had been carried on.

The venous pressure may be elevated in emphysema in the absence of failure, or may be normal at rest and rise on exercise. This increase in venous pressure in the absence of cardiac failure has usually been ascribed to an increase in intra-pleural pressure.

The x-ray and electrocardiogram are of great value in the diagnosis of cor pulmonale prior to the onset of failure. X-ray findings are of limited value in those patients with advanced tuberculosis or silicosis which renders evaluation of the cardiac silhouette difficult, but are of considerable value in patients with emphysema. Enlargement of the pulmonary arteries is frequent, and enlargement of the pulmonary conus is frequently the first indication of cardiac enlargement. Enlargement of the body of the right ventricle is less frequently seen. The transverse diameter of the heart usually is enlarged only in the presence of failure. Angiocardiography in emphysema is reported as showing a high percentage of right ventricular dilatation. The use of a barium swallow to outline the esophagus is of value in differential diagnosis of mitral disease and its accompanying left auricular enlargement. Fluoroscopy in primary pulmonary vascular disease is characterized by a large pulsating pulmonary artery and right ventricular hypertrophy.

With the routine use of 13 leads, the electrocardiogram is of great value in the diagnosis of right ventricular hypertrophy. Our accuracy in diagnosing cor pulmonale has increased since we have been taking routine electrocardiograms of tuberculous patients and medical patients with chronic lung disease using the three standard leads, unipolar limb leads, $V_R$ and $V_I-V_a$. The characteristic findings consist of high R-waves in leads over the right precordium, and deep S-waves in leads over the left precordium; depression of the S-T intervals and T-waves inversions over the right side of the heart are also of considerable diagnostic value. A high, peaked P-wave in leads 2 and 3 and the left leg lead, and the presence of a Q-wave and high R-wave in the right arm lead, are also of value in determination of cor pulmonale. Due to the markedly vertical position of the heart with clockwise rotation, the chief findings may be low to absent $R$-waves in chest leads $V_I-V_a$, with $R$-waves becoming more prominent as the leads are shifted one or two interspaces below the conventional levels. Electrocadiographic changes which would be equivocal if seen in a single curve become of diagnostic value when compared with previous records. Additional exploratory leads over the right chest may be of value in cases where right ventricular hypertrophy is suspected and the orthodox leads are not diagnostic. It has been our experience that the electrocardiogram will show evidence of right ventricular hypertrophy before it can be demonstrated by x-ray inspection. In a certain proportion of patients definite right ventricular hypertrophy will be found at post mortem in whom electrocardiogram and x-ray findings are within normal limits and physical examination has not revealed definite evidence of cardiac involvement.
The intensive studies of cardio-respiratory physiology in recent years have focused attention on the circulatory and cardiac changes seen in chronic pulmonary disease, and have placed therapy on a more rational basis. The importance of acute anoxia in causing pulmonary hypertension has been emphasized. In the patient with chronic pulmonary disease the pulmonary vascular bed is reduced by the anatomic lesions, and anoxia and polycythemia further increase the disproportion between pulmonary blood flow and capacity of the pulmonary vascular bed. In the past, and as recently as 1951, the grave prognosis of cardiac failure in chronic cor pulmonale has been stressed, but in our experience failure of this type may respond well to treatment consisting of the usual measures of rest, digitalization, salt restriction, mercurial diuretics and oxygen. Phlebotomy is used if the hematocrit is over 60 per cent, and antibiotics are used at the slightest suspicion of pulmonary infection. Bronchodilators (particularly ephedrine) are of value and are continued after the attack of failure is relieved. Potassium iodide is used as an expectorant.

SUMMARY

1) Autopsy findings from November, 1948, to October, 1951, at this hospital demonstrated an incidence of right ventricular hypertrophy of 50 per cent in patients with pulmonary tuberculosis and chronic emphysema.

2) Chronic cor pulmonale is much more frequently seen at autopsy than the clinical diagnosis would indicate. Awareness of the situation in which cor pulmonale is particularly prevalent, and the use of appropriate diagnostic study, should make clinical appraisal of the patient more accurate and lead to more effective treatment and more intelligent prognosis.

RESUMEN

1) Los hallazgos de autopsia de Noviembre de 1948 a Octubre de 1951 en este hospital, demuestran la frecuencia de la hiperтроfia ventricular derecha que es de 50 por ciento de los enfermos con tuberculosis pulmonar y enfisema crónico.

2) El corazón pulmonar agudo es mucho más frecuente encontrado en la autopsia de lo que el diagnóstico clínico haría suponer. Una alerta sobre las situaciones en las que el cor pulmonale es particularmente prevalente y el uso de medios adecuados de diagnóstico, permitirán una estimación más exacta del estado clínico del enfermo así como conducirían a un tratamiento más efectivo y a un pronóstico más inteligente.

RESUME

1) Les auteurs rapportent les constatations faites au cours des autopsies pratiquées dans leur service d’hôpital de 1948 à octobre 1951. Elles montrent la fréquence de l’hypertrophie ventriculaire droite que se vérifia chez 50% des malades atteints de tuberculose pulmonaire et d’emphysème chronique.

2) Le coeur pulmonaire apparaît bien plus fréquemment à l’autopsie que ne le laisserait prévoir le diagnostic clinique. Celui-ci devrait être plus facilement porté compte tenu de la fréquence du coeur pulmonaire et de
l'utilisation des moyens d'investigation appropriés. Ainsi pourraient être établis un traitement plus efficace et un pronostic plus rationnel.

REFERENCES

16 Cited in 9.