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The Diagnosis of Chronic Cor Pulmonale

James F. McMurry Jr.

Ralph D. Parks

This review of cor pulmonale is oriented to the improvement of accuracy of diagnosis on clinical grounds.—Ed.

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James F. McMurry, Jr., M.D.*, and Ralph D. Parks, M.D.**

Cases of cor pulmonale can be divided into acute and chronic. The acute cases are usually due to pulmonary embolism. This presentation will be limited to chronic cor pulmonale. Dorland's Medical Dictionary[1] defines cor pulmonale as heart disease secondary to pulmonary disease. Called to discuss this topic in 1961, the W.H.O. Expert Committee,[2] stated that chronic cor pulmonale is best defined as right ventricular hypertrophy due to pulmonary disease, specifically excluding congenital heart disease and conditions such as mitral stenosis which can secondarily cause pulmonary hypertension and hence right ventricular hypertrophy. Anatomically we see: 1) some form of chronic pulmonary disease and 2) an increase in tissue mass of the right ventricle. Right ventricular hypertrophy is defined pathologically as thickness of the free wall of the right ventricle of 5 mm or greater or an increase in weight of the carefully dissected free wall of the right ventricle—or even a disparity in the ratio of right ventricular to left ventricular weights. Fulton's criteria[3] of right ventricular hypertrophy are a right ventricular weight of 80 gm or more, or a ratio of left ventricular weight (with septum) to right of less than 2:1.

The W.H.O. Committee lists *many* causes of cor pulmonale; Vance[4] says 85-90% of cases are due to chronic bronchitis and emphysema. Other causes listed by the W.H.O. Committee[2] are pulmonary fibrosis from tuberculosis, pneumoconiosis, bronchiectasis, pulmonary mycosis, radiation or mucoviscidosis; pulmonary granulomata and infiltrations from sarcoidosis, chronic diffuse intersitial fibrosis, berylliosis, histiocytosis, scleroderma, systemic lupus erythematosus, dermatomyositis, alveolar microlithiasis or, malignant infiltrations; pulmonary resection; congenital cystic disease of the lungs; high altitude hypoxia; disease affecting the movement of the thoracic cage including kyphoscoliosis, thoracoplasty, pleural fibrosis, chronic neuromuscular disease

*Resident in Medicine, Henry Ford Hospital.
**Associate Physician, Division of Pulmonary Diseases, Henry Ford Hospital.

such as poliomyelitis, Pickwickian syndrome, and idiopathic alveolar hypoventilation. Also, a large number of diseases affecting the pulmonary vasculature including polyarteritis nodosa, primary pulmonary hypertension, primary pulmonary thrombosis, sickle cell anemia, schistosomiasis, malignant embolism, other embolic phenomena, and pressure of major pulmonary vessels from mediastinal tumors, aneurysm, or granulomas or fibrosis. It is easy to understand why cor pulmonale is the fourth most common type of heart disease in the United States—superseded by arteriosclerotic, hypertensive and rheumatic heart disease.

History

There is debate about whether any symptoms are specifically related to right ventricular hypertrophy. The common symptoms of heart failure, dyspnea and easy fatigue, are also symptoms of pure pulmonary insufficiency. Thus these cannot be used to distinguish the patient with pulmonary disease alone from one who has pulmonary disease *and* cor pulmonale. Some clinicians[5,6] feel that right upper quadrant discomfort may lead to the finding of hepatic congestion, which may signify right ventricular failure. Substernal discomfort lasting several hours and occurring with exercise has been described. There is disagreement as to whether this symptom is related to right ventricular ischemia, whereby it might be considered as symptomatic of failure, or whether this is due to distention of pulmonary vessels, in which case it could be a symptom of pulmonary hypertension alone. The patient that complains of pedal edema may or may not have right ventricular failure. It is known that ankle edema can occur in emphysema without the presence of right ventricular failure.

In summary, we can say that cor pulmonale cannot be diagnosed by listening to the patient. But, in listening to the patient, we may be stimulated to search for a diagnosis of cor pulmonale.

Physical Findings

In examining the patient with cor pulmonale one must be careful to take into consideration the modification of cardiovascular signs that the pulmonary disorder produces. Obstructive lung disease may be associated with edema in the absence of heart failure. Phillips and Burch[5] comment that rapidly changing or severe edema is a reasonable indicator that right heart failure *is* present. When examining the liver one must take into account the inferior descent of that organ which is due to enlargement of lung volume with a lower diaphragm. This naturally means we must percuss the superior as well as inferior margins of the liver, the normal liver measuring less than 10-12 cm. Palpation of a right ventricular thrust is considered to be a good indicator of cor pulmonale. In fact, the W.H.O. Committee suggests that this is the only physical sign directly related to right ventricular hypertrophy. This systolic event has been described as a "footward-forward systolic thrust of the inferior cardiac border." It may be found in the left lower parasternal area or, in the presence of hyperinflated lung, it may be best palpated in the epigastrium. It should be borne in mind that the pulsation of the abdominal aorta may be mistaken for it. A maneuver similar to the differentiation of indirect inguinal hernias may be used. If

the palpating hand is placed flat in the epigastrium, then the fingers are pushed upward behind the xiphoid; a pulse felt on the finger tips can be readily distinguished from one directing its thrust to the palmar surface. Light palpation just at or below the xiphoid often reveals a sharp tap that is not difficult to distinguish from the large volume thrust of the aorta

Auscultation of the heart[2,5,6,7] in the emphysematous patient is frequently very difficult because the large volume of air between heart and chest wall is a poor conductor of sounds. Nevertheless, auscultation in cor pulmonale is very important and can yield valuable information, generally, about the presence of pulmonary hypertension or right heart failure rather than right ventricular hypertrophy.

The classic physical sign[7] of pulmonary hypertension is accentuation of the pulmonic component of the second heart sound as judged by alternate listening at either side of the sternum (recalling the normal louder sound in the aortic area). There are three other auscultatory signs of pulmonary hypertension: a pulmonic ejection sound, pulmonic ejection murmur, and the diastolic murmur of pulmonic insufficiency (Graham Steell murmur). Pulmonic ejection sounds or clicks occur shortly after the first heart sound and may be confused with splitting of the first heart sound or an aortic ejection click. The latter is differentiated by the selective accentuation which occurs in expiration in the pulmonic click. This sound also occurs in pulmonic valvular stenosis or idiopathic dilatation of the pulmonic artery. A dilated pulmonary artery may give rise to a crescendo-decrescendo systolic murmur. Functional pulmonic valve insufficiency produces the decrescendo diastolic (Graham Steell) murmur beginning with or just after the usually accentuated pulmonic second sound. In emphysema, all of these sounds may be dampened to extinction.

A right ventricular gallop is a standard sign of right ventricular failure. A right-sided gallop is distinguished by 1) its location at the lower sternum or epigastrium rather than the apex and 2) the tendency of the right ventricular gallop sound to intensify with inspiration. The systolic murmur of tricuspid insufficiency in cor pulmonale may be attributed to gross dilatation of the right ventricle. It is an important finding and signifies severe heart disease. It is frequently heard best in the epigastrium and becomes louder in inspiration (Carvallo's sign), which distinguishes it from mitral insufficiency.

In assessing the jugular venous pulse, it must be remembered that in obstructive lung disease the patient's veins are frequently bulging due to the increased intra-thoracic pressure developed in attempting to expire through an obstructed bronchial tree. By digital examination one may demonstrate retrograde filling of the veins during inspiration as well as expiration. A "hands-off" sign of severe right ventricular incompetence (or restrictive pericardial disease) was described by Kussmaul about 80 years ago.[8] Normally the cervical veins collapse when intrathoracic pressure becomes negative. When the right ventricle cannot accommodate or propel the increased systemic venous return during inspiration, the cervical veins distend. This

has achieved widespread popularity as a sign of right heart failure of any cause. In the patient with advanced tuberculosis, it may signify either constrictive pericarditis or cor pulmonale.

The direct measurement of venous pressure is considered so unreliable in cor pulmonale that several authors[2,5,6] discourage its use. The principal reason is the difficulty of establishing the "phlebostatic axis" in the barrel-chested patient. For those so inclined, however, it is recommended that the best baseline is 10 cm from the back — rather than measuring from the front of the chest. Regarding the measurement of the circulation time, Phillips and Burch bluntly state that, "This determination is not of great value in the diagnosis of cor pulmonale." They further explain that, "If significant cor pulmonale with right ventricular failure is present, however, the arm-to-tongue circulation time is likely to be prolonged; but cor pulmonale affects primarily the arm-to-lung time whereas the lung-to-tongue time is near normal." The hyperkinetic state that some patients demonstrate may also contribute to the unreliability of this test.

Radiographic Diagnosis

The radiographic demonstration of cor pulmonale[9] is fraught with difficulty. The right ventricle may be seen to enlarge on a PA film, but since it normally contributes little to the contours in this projection, it is difficult to say whether it is right or left ventricular enlargement. There is one area — the pulmonary conus — which is fairly specific. Flattening of the notch between the aortic knob and the left ventricular border usually signifies dilatation or hypertrophy of the conus or outflow tract of the left ventricle. In the lateral projection, the "filling in" of the anterior space between sternum and heart suggests right ventricular dilatation or hypertrophy. In those 85% of patients with cor pulmonale in whom right ventricular enlargement is secondary to obstructive disease, hyperinflation may prevent this "filling in" phenomenon. Several authors[5,6,9,19] emphasize the use of *serial* chest x-rays in following patients who are prone to develop cor pulmonale, and in this way cardiomegaly (particularly enlargement in the areas noted), becomes more reliably and more readily assessed.

Electrocardiographic Diagnosis

The electrocardiographic diagnosis of cor pulmonale (right ventricular hypertrophy due to pulmonary disease) is a topic of much debate, and correspondingly much confusion. There are several reasons for this. In the normal adult the right ventricle contributes little to the QRS-T portion of the electrocardiogram. Relatively large changes in the muscle mass of the right ventricle may produce little or no change in the recorded potentials.[5,10] It is well documented by many authors that patients with obvious hypertrophy of the right ventricle may reach the autopsy table with a normal electrocardiogram hours or days before their demise. To make matters worse, there is a large number of patients in whom the ECG diagnosis of RVH is falsely positive. One group of electrocardiographers was satisfied to accept 30% false positives when they published their criteria for the ECG diagnosis of pulmonary heart disease.[10] In

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sifting out criteria for the ECG diagnosis of cor pulmonale one should consider the contribution that the underlying emphysema, pulmonary fibrosis, chest deformity, etc., make to the recorded electrical events. Emphysema or hyperaeration alters the electrocardiogram in several ways. The apex of the heart tends to follow the diaphragm down to a lower position creating a more vertical anatomic and electrical axis. The right ventricle tends to rotate anteriorly — or perhaps the left ventricle rotates posteriorly. The interposition of more air between heart and chest wall also tends to insulate the heart from exploring precordial electrodes. Some authors have proposed electrocardiographic criteria for the diagnosis of emphysema.[10,11,12,13,14] These generally place great emphasis on rightward deviation of the P axis and QRS axis which they say may be due to a change in anatomic position of the heart rather than a relative increase in right ventricular muscle mass.

Grant[15] recommended the following as signs of right ventricular hypertrophy: 1) right axis deviation of the QRS vector, 2) tall R waves greater than 0.04 sec. in V_1 and 3) an RSR' in V_1 with a QRS complex of normal duration.

We have already noted the possibility of right axis deviation being misleading. A tall, broad R in V_1 may also be caused by a true posterior myocardial infarct or may be found in the Type A Wolff-Parkinson-White syndrome. An RSR' pattern in V_1 may, of course, be due to right bundle branch block when the QRS duration approaches 0.12 second. Even in the absence of block there are other causes. If this particular pattern is associated with left axis deviation, it signifies parietal or peri-infarction block. Grant felt that the association of right axis deviation and an RSR' pattern in V_1 makes the diagnosis of right ventricular hypertrophy due to cor pulmonale a virtual certainty. A final association of the RSR' pattern is the so-called "$S_1S_2S_3$ syndrome". This may be due to RVH or myocardial infarction or may even be normal in young persons. This latter phenomenon—the $S_1S_2S_3$ syndrome, is associated with a QRS vector pointing rightward and superiorly. In the patient with cor pulmonale this is readily explained as hypertrophy of the crista supraventricularis— the outflow tract of the right ventricle.

In a recent paper reporting vectorcardiographic studies in cor pulmonale, Walsh[16] states that the cardiac abnormalities in cor pulmonale pass through three successive stages. The first stage involves dilatation and hypertrophy of the outflow tract, particularly the crista supraventricularis. Later, dilatation and hypertrophy of the body of the right ventricle occurs. In the final stage, greater right ventricular hypertrophy and dilatation are seen with tricuspid insufficiency and right atrial hypertrophy. Thus, the appearance of a "crista pattern" in a patient with pulmonary disease may be an early clue to the presence of cardiac involvement. Unfortunately, its absence does not rule out the diagnosis.

Other popular criteria[10,11,12] in the ECG diagnosis of pulmonary heart disease are the ratios of R to S wave in V_1 and V_6. In V_1 an R greater in amplitude than the S wave seems to be a fairly good indicator of RVH. A recent report[10] has denied the necessity of a specified 5 or 7 mm height of the R wave before it can be said to be

significant—an R/S ratio greater than 1 seems to be sufficient. The converse, an S equal or deeper than the amplitude of the R in V_6, is considered by Burch and Depasquale to be a highly significant finding when present. They note, however, that 40% of the patients in their study with autopsy-proven cor pulmonale satisfied none of their electrocardiographic criteria for right ventricular hypertrophy. In one of the most recent studies[3] on the ECG in chronic lung disease, an excellent correlation between right axis deviation and the presence of right ventricular hypertrophy was found. In this study, Millard examined the electrocardiograms of 46 patients who were autopsied and had some form of chronic lung disease, largely chronic bronchitis and emphysema. He used the pathologic criteria of Fulton, whereby RVH is said to be present if the right ventricular weight is greater than one half that of the left ventricle with septum (perhaps the most sensitive criterion) or the right ventricle weighs 80 gm or more—regardless of left ventricular weight. He concluded that right axis deviation of 91° to 180° would accurately diagnose RVH unless left ventricular disease was also present. In the cases with borderline axis (barely over 90°) he found the right ventricle to be borderline in weight but hypertrophied if the ratio of right to left was used. He further supplied data on patients in whom hyperinflation was definite radiographically and found that the 90° division accurately separated those cases with anatomic RVH.

Before leaving the ECG, the P wave should be mentioned. The peaked P of cor pulmonale (i.e., greater than 2.5 mm in leads II or III) is a helpful, but definitely inconstant finding. It has been suggested[10,16] that many patients died of their lung disease before they developed sufficient cardiac disease to have right atrial hypertrophy. One group[12] has, however, documented this as a transient event in some of their patients.

Pathophysiology and Therapy

Before concluding, it would be apropos to discuss the pathogenesis of chronic cor pulmonale and certain therapeutic implications. Chronic cor pulmonale is basically the end result of the right ventricle being unable to cope with pulmonary hypertension. Pulmonary hypertension can be produced by active vasoconstriction or obliteration of a portion of the pulmonary vascular bed. The former is the case in hypoventilatory states (in the broadest sense of the word) and the latter in the vasculitic and embolic disorders. The two most potent stimuli to vasoconstriction in the pulmonary arterial tree are hypoxia and acidosis.[6,17,18,19] Ferrer and Harvey (at Bellevue) have continued studies begun with Cournand and Richards that show straight line relationships between decreasing O_2 saturation and increasing pulmonary arterial pressure. More recently,[18] they have demonstrated rising pulmonary artery pressure by infusing weak concentrations of hydrochloric acid into patients with obstructive lung disease. The effect of pH and hypoxia on pulmonary artery pressure tells a striking and significant story that emphasizes the overwhelming importance of the careful management of ventilation in the patient with cor pulmonale. Authors who are writing about the therapy of patients with cor pulmonale, secondary to obstructive lung disease[4,6] correctly place strong emphasis on the management of the dysfunction of the respiratory system, rather than the heart. This is not to say that digitalis and diuretics are not important, but the emphasis is clear.

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This brings to mind the frequently repeated concept that digitalis is not helpful in cor pulmonale. In 1950, the Bellevue group[20] studied patients shortly after admission for cor pulmonale by doing cardiac catherization and administering digoxin intravenously during the study. They consistently found that patients in clinical heart failure had an elevated end-diastolic pressure in the right ventricle which responded dramatically to digoxin. Cardiac output increased and end-diastolic ventricular pressure reverted to near normal. Simultaneously, the already elevated pulmonary artery pressure climbed a bit higher with increased flow. A few weeks later these patients were restudied and right ventricular end-diastolic pressures, cardiac outputs and even pulmonary arterial pressure were essentially normal. A side benefit was an increase in vital capacity. It seems likely therefore that digitalis is as useful to the failing right ventricle as it is to the left. Adjunctive measures, however, are of even more importance. These include maintainance of adequate alveolar ventilation, correcting hypoxemia and acidosis, combating fluid retention and vigorous attempts to correct the decompensated lung.

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