Acutely left ventricular failure frequently, if not always, produces acute left atrial distention. Such distention, if clinically recognizable, would be a useful sign of left ventricular failure, a disorder that notoriously may lack discriminatory findings. Angiocardiography that may specifically diagnose left atrial distention, and cardiac catheterization that may specifically diagnose acute left ventricular failure are not practical procedures simply to establish such diagnoses.

The purpose of this study is to show that acute changes in the electrocardiographic P waves are useful and perhaps sensitive signs of acute left ventricular failure.

**Material and Methods**

The records of 104 patients whose discharge diagnoses included cardiac insufficiency were carefully reviewed. Of these 104, 26 records were available of patients who were admitted into the hospital with acute left ventricular failure and with electrocardiographic evidence of sinus rhythm both during failure and compensation, but who were free from signs of right-sided failure. Nine of these 26 had acute pulmonary edema on admission.

There were 17 men and 10 women, 33 to 86 years of age, with an average of 62 years. Sixteen had coronary artery disease, seven hypertension, one myocardial disease, and one mitral stenosis. In one, the cause of failure was not determined.

The P waves were carefully examined in the electrocardiogram taken during the episode of failure and in a subsequent tracing obtained after failure was adequately controlled. If a subsequent tracing was not available, one preceding the failure was examined. The P-wave axes in the frontal and horizontal planes were measured and the height and duration of all P waves were measured. The P:PR segment ratio was determined after the method of Macruz, Perloff, and Case. The positive and negative deflections of the P waves in V1 were measured and added algebraically. The result obtained in the electrocardiogram taken when the patient was compensated was subtracted from that when the patient was in failure. A negative figure was taken to indicate posterior shift of the atrial vector in failure, and a positive figure suggested anterior shift. This figure will be referred to as "V1 difference." Abnormal contour of the P wave, such as notching, was noted as well as the precordial lead furthest to the left in which was found a negative P-wave deflection.

**Results**

Changes in the height and duration of the P waves during left ventricular failure are shown in table 1.

The average direction of the mean atrial vector in the frontal plane during compensation was +50°; during left ventricular failure, +46°. Fifteen demonstrated a leftward shift of the P wave in the frontal plane and four a rightward shift during failure. But in only seven (27 per cent) was the leftward shift greater than 10°. Seven (27 per cent) showed no shift.

The P:PR segment ratio increased in 13 (50 per cent), decreased in six (23 per cent), and was unchanged in seven (27 per cent). Because of the errors inherent in this measurement, limiting a significant increase of the ratio to more than 0.1 difference appears reasonable. If such a standard is used, the increase in P:PR segment ratio decreased to 36 per cent.

Twenty had a negative V1 difference. In 12, the negative deflection of the P wave extended farther to the left on the precordium during failure than during compensation. With these two criteria as evidence of posterior rotation of the atrial vector, 21 (81 per cent) had such rotation during the episode of failure. These findings are shown diagrammatically in figure 1, and representative electrocardiograms appear in figure 2.
Abnormal contour of P waves, particularly notching, was present in 20, but in only four did the notching increase during failure. These four demonstrated posterior rotation of the atrial vector.

**Discussion**

The relationship of left ventricular disease to deformities of the atrial complex is suggested by the old observation of the frequency of notched P waves in syphilitic aortic regurgitation. The relationship of right ventricular disease to deformities of the atrial complex is well documented.

Angiocardiography has clearly shown that left atrial enlargement is a common complication of left ventricular disease. It appeared likely, therefore, that the P wave would reflect this enlargement. Indeed, Sodi-Pollares

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**Table 1**

Changes in Height and Duration of P Waves during Left Ventricular Failure

<table>
<thead>
<tr>
<th>Height of P waves</th>
<th>Duration of P waves</th>
</tr>
</thead>
<tbody>
<tr>
<td>Limb leads</td>
<td>Precordial leads</td>
</tr>
<tr>
<td>Increased in failure</td>
<td>10</td>
</tr>
<tr>
<td>Decreased in failure</td>
<td>8</td>
</tr>
<tr>
<td>No change</td>
<td>8</td>
</tr>
</tbody>
</table>

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*Figure 1*

Diagrammatic outline of the voltage (×10) and of the direction of P from V1 to V6 (a) during failure and (b) during compensation.
stated that changes in the morphology of P, or a shift of its axis to the left, are often the earliest electrocardiographic signs of essential hypertension. Martins deOliveira and Zimmerman² pointed out that there is some electrocardiographic influence on the atria of almost all conditions that result in ventricular overloading.

It appears likely, therefore, that atrial abnormalities secondary to left ventricular disease will resemble those seen in mitral valve disease. These abnormalities consist of widened P waves, which are frequently slurred and notched, and may have unusually long intervals between the peaks of the bifid P.⁶ It is almost universally stated that the frontal plane vector of P is rotated to the left in left atrial enlargement.⁴

Many investigators believe that the degree of abnormality is proportional to the degree of left atrial enlargement.⁴⁷ Thus, the degree of left axis deviation in the frontal plane of P,⁴ the duration of P,⁵ the voltage of P and the interval between the peaks of the bifid P⁶ are regarded as determined by the size of the left atrium. The use of the P:PR segment ratio of Macruz, Perloff, and Case¹ implies this relationship.

None of these factors showed changes that were helpful in distinguishing left ventricular failure from the compensated state. If left ventricular failure were actually associated with acute left atrial distention, it can be concluded that these factors are not related to the degree of left atrial enlargement.

In their studies on the P wave in mitral stenosis, Soloff and Zatuchni⁸ had evaluated these factors as indices of left atrial enlargement measured by biplane angiocardiology, and found no significant correlations. These conclusions are now substantiated by a review of our biplane angiocardigrams that now number close to 1,000. It should be particularly emphasized that the almost universal statement that left atrial enlargement produces leftward deviation of the atrial vector in the frontal plane is contrary to our data.

None of these criteria, however, has been used, to our knowledge, as a sign of left ventricular failure. Wood and Selzer⁹ in 1939 pointed out that the configuration of the P wave might be a useful diagnostic sign in left ventricular failure. They described a wide P wave with low voltage, usually bifid or flattopped, often with a duration of 0.12 second, and rarely greater than 1 mm. in amplitude. This was felt to differ from the more prominent "P-mitrale" of mitral valve disease, and contrasted markedly with the tall spiked "P-pulmonale" often seen in patients with right ventricular hypertrophy. Our data fail to confirm their findings, and we have been unable to find any confirmation in the literature. These findings are, however, commonly present with left ventricular disease without failure, and will persist when failure develops.

Figure 2

Seven instances of P₅ in failure, top; in compensation, bottom.
A re-inspection of Soloff and Zatuchni’s data on the relationship between the P wave and the size of the left atrium\textsuperscript{10} indicates clearly that increased size of the negative component of the P wave in the right precordial leads is correlated with increasing size of the left atrium. Others have suggested a relationship between the depths of these negative components and left atrial enlargement but not its degree.\textsuperscript{11} Furthermore, Soloff and Zatuchni’s data\textsuperscript{10} indicate a relationship between the distribution of the negative component of the P wave on the precordium and the size of the left atrium. Both these correlations have been verified by a review of more extensive data. These observations suggest that the posterior displacement of the atrial vector in acute left ventricular failure is actually due to acute left atrial dilatation. Abrupt posterior displacement of the atrial vector can also be produced in some subjects with mitral stenosis by simple setting-up exercises,\textsuperscript{12} and are also probably due to left atrial distention secondary to left atrial failure.

Regardless of its mechanism, however, sudden posterior displacement of the atrial vector is a reliable sign of, and is present in over 80 per cent of left ventricular failure in the absence of mitral valve disease. Abrupt increased notching of the P wave and the sudden onset of atrial fibrillation in left ventricular disease probably also indicate left ventricular failure. This appears to be equally true of other atrial arrhythmias that we have seen but are not included in this series. In our series, however, all such incidents were associated with posterior displacement of the P vector when sinus rhythm was restored.

**Summary and Conclusions**

The electrocardiograms of 26 patients with a clinical diagnosis of acute left heart failure were examined to determine if there were any electrocardiographic signs that could distinguish the tracing taken during failure from that taken during compensation.

In 21 (81 per cent), failure was associated with a posterior rotation of the mean atrial vector in the horizontal plane, demonstrated by an increase in P-wave negativity in V\textsubscript{1} or persistence of a negative deflection of the P wave farther to the left in the precordial leads.

Atrial fibrillation and increased notching associated with failure occurred in some patients, but were also accompanied by posterior rotation of the P vector when sinus rhythm was restored.

Other atrial abnormalities present were not significantly changed during failure.

Posterior rotation of the atrial vector is an important electrocardiographic sign of acute left ventricular failure.

**References**

Posterior Rotation of the Atrial Vector: An Electrocardiographic Sign of Left Ventricular Failure

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