2-O Interval as an Indicator of Left Atrial Pressure*

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The time interval between the aortic closure sound and O point of the apexcardiogram (2-O interval) was determined in a group of 38 normotensive patients and correlated with the mean left atrial or pulmonary capillary wedge pressure. Twenty-three patients had an elevated left atrial pressure and an average 2-O interval of 0.076 seconds. Fifteen patients had a normal left atrial pressure with an average 2-O interval of 0.10 seconds. Both normal and abnormal left atrial pressures occurred at 2-O intervals of 0.08 seconds or more. A 2-O interval of 0.07 seconds or less was associated with a left atrial pressure of 18 mm Hg or more. On the basis of this study, it is concluded that the 2-O interval is a simple, accurate, non-invasive method of predicting an elevated left atrial pressure in normotensive patients with severe coronary artery or myocardial disease.

**METHODS**

Thirty-eight normotensive patients between 13 to 67 years of age were studied. Fifteen of the patients were normal. Twenty-three of the patients had either severe coronary artery or myocardial disease. None of the patients had valvular heart disease. Cardiac catheterizations were performed on all patients and either a PCWP or LAP using transseptal technique was obtained. All pressure recordings were done on an Electronics for Medicine recorder using a Statham transducer. Phonocardiograms were recorded either immediately prior to or during the cardiac catheterization. The apexcardiogram and second heart sound were recorded on a Sanborn twin-beam model no. 62 phonocardiographic recorder at 75 mm/sec paper speed with 0.04 second time line intervals. Sound recordings were obtained from the left sternal border and apex simultaneously with an apexcardiogram. The aortic closure sound was identified as the first, largest negative deflection of the second heart sound. The apexcardiogram was recorded by placing a linear microphone over the left ventricular impulse or PMI. The patients were turned into the left lateral position to facilitate recording of the apical impulse. The O point was identified as the nadir of negative deflection following the systolic positive deflection. The time interval from aortic closure to the O point of the apexcardiogram in a group of 38 patients using standard phonocardiographic technique.

**RESULTS**

The correlation of left atrial pressure and 2-O interval in the 38 patients is presented in Figure 1.
The overall correlation coefficient for the total group of patients was $-0.6$. In the 15 patients with no evidence of cardiac disease, the left atrial or wedge pressure ranged from 3-11 mm Hg (average 8 mm Hg) and the 2-O interval ranged from 0.14-0.08 seconds with an average of 0.10 seconds. The correlation coefficient in this group of normals was also $-0.6$. Twenty-three patients with evidence of cardiac decompensation were found to have severe coronary artery or myocardial disease. Mean left atrial or pulmonary wedge pressure ranged from 15-45 mm Hg (average 21 mm Hg) and the 2-O interval ranged from 0.10-0.055 seconds (average 0.076 seconds). The correlation coefficient for this group of abnormals was $-0.7$. As can be seen in Figure 1, when the 2-O interval was 0.08 seconds or more, estimation of left atrial pressure was difficult because of overlap between the normal and abnormal groups. A 2-O interval of 0.07 seconds or less, however, was associated with an elevated left atrial pressure of 18 mm Hg or more. In general, if the 2-O interval was as short as 0.06 seconds the left atrial pressure was markedly elevated.

**Comment**

Since Marcy$^{4,7}$ first recorded the apexcardiogram in man in 1885 a great deal has been learned regarding its hemodynamic correlation. The apexcardiogram is one of the few noninvasive methods available for timing diastolic intracardiac events.$^{5,8}$ The O point of the apexcardiogram coincides with the beginning of ventricular filling and occurs when the left atrial pressure exceeds the left ventricular pressure. Figure 2 is a diagram which demonstrates the relationship of the apexcardiogram with left sided cardiac events. Hemodynamically the interval between the aortic component of the second heart sound and the O point of the apexcardiogram is
referred to as the isovolumetric relaxation period (IRP). The general factors which influence the IRP or 2-O interval have recently been described. These factors include the left ventricular end-systolic pressure (pressure at the time of aortic valve closure), the rate of relaxation of the left ventricle, and the left atrial “v" wave pressure. While the IRP is not influenced by age or heart rates under 140 per minute, exercise and isoproterenol have been shown to produce a decrease in the IRP. On the other hand, digitalis increases the IRP. The wide variation of the 2-O interval in normal patients can best be explained on the basis of a varying rate of left ventricular isovolumetric relaxation. When the LAP is elevated, however, the rate of ventricular relaxation should have relatively less effect on the IRP or 2-O interval because of the earlier occurrence of left ventricular filling. To our knowledge a study correlating the IRP with LAP in patients without mitral stenosis has not previously been reported. If the patient is normotensive and the rate of isovolumetric relaxation remains relatively constant, the 2-O interval should correlate with the LAP.

Patients with mitral stenosis provide a model for the estimation of LAP by the timing of diastolic events. In these patients the time interval between the aortic component of the second heart sound and the opening snap, called the 2-OS interval has been shown to correlate reasonably well with the LAP. The 2-OS interval in these patients has also been shown to shorten with exercise as the LAP increases. It has also been demonstrated in mitral stenosis that the opening snap occurs at approximately the same time as the O point on the apexcardiogram and that the 2-OS interval is therefore equal to the 2-O interval using the apexcardiogram. Figure 3 shows an example of this relationship. This figure represents the findings in a 35-year-old woman with dyspnea secondary to mitral stenosis. The opening snap coincides with the O point of the apexcardiogram and the 2-OS or 2-O interval in this patient falls within a normal range and correlates with the normal wedge pressure.

Our study shows that the 2-O interval correlated reasonably well with the LAP in coronary artery or myocardial disease. The graph in Figure 1 shows this correlation. Figure 4 represents the findings in a 49-year-old man with severe angina, symptoms of congestive heart failure, and data at cardiac catheterization compatible with severe coronary artery disease and left ventricular dysfunction. The mean LAP by transseptal catheterization was 45 mm Hg. The 2-O interval recorded simultaneously with the LAP in the catheterization laboratory using standard phonocardiographic technique was 0.055 seconds. The short 2-O interval correlated with the elevated LAP in this patient. This case illustrates that the 2-O interval becomes shorter as the LAP
increases. With a little practice the apexcardiogram can be obtained very consistently in most patients and the aortic closure sound is easily recorded on the phonocardiogram. The 2-O interval may be a practical method of estimating the LAP in office practice or in the hospitalized patient at bedside. There are several limitations inherent in this method, however. One of these is that the apexcardiogram is difficult to obtain in patients who are obese, have chronic obstructive pulmonary disease, or a recent thoracotomy. Also, an elevated blood pressure lengthens the 2-O interval since aortic closure occurs earlier due to the elevated end-systolic pressure. The 2-O interval can, however, be corrected for the elevated blood pressure by the method described by Ebringer. The most serious limitation of this technique is that there is considerable overlap between patients with abnormal left atrial pressures and normals at 2-O intervals of 0.08 seconds or more. Therefore, this indirect measurement allows separation from normal at only relatively high levels of left atrial pressure.

REFERENCES
1 Hultgren HN, Flamm MD: Pulmonary edema. Mod Concepts Cardiovasc Dis 38:1-6, 1969

Editorial Expression

The study and use of noninvasive techniques for assessing cardiac function and performance represent a most dynamic and potentially useful trend in cardiology today. The advantages of these techniques lie not only in their relative ease and atraumatic nature but also in their ability to allow short and long term serial measurements and objective patient follow up. Most such techniques, however, suffer from shortcomings and limitations. These relate to a relative lack of specificity and precision and the difficulty to clearly separate the effects of concurrent hemodynamic variables on some of the measurements obtained. Nevertheless and as a result of enthusiasm being generated in this area, the “noninvasive laboratory” is gaining acceptance and recognition as an important adjunct in evaluation and follow up of cardiac patients. The above article illustrates both the advantages and shortcomings just mentioned and represents a simple and modestly useful technique to be added to a growing list.

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