THE APEX CARDIOGRAM IN THE STUDY OF THE 2-OS INTERVAL*

BY

JEAN F. LEGLER, ALBERTO BENCHIMOL, AND E. GREY DIMOND

From the Institute for Cardio-Pulmonary Diseases, Scripps Clinic and Research Foundation, La Jolla, California

Received August 14, 1962

Since the report in 1932 by Margolies and Wolferth on the opening snap in mitral stenosis, attempts have been made to evaluate this lesion by phonocardiography (Messer *et al.*, 1951; Mounsey, 1953; Wells, 1954; Kelly, 1955; Bayer, Loogen, and Wolter, 1956; Craige, 1957; Julian and Davies, 1957; Steinzeig, *et al.*, 1957; Wells, 1957; Di Perri and Fabrizi, 1958; Proctor *et al.*, 1958; Donnelly, Maha, and Orgain, 1959; Leo and Hultgren, 1959; Rich, 1959; Dack *et al.*, 1960; Muiesan *et al.*, 1960; Nixon, Wooler, and Radigan, 1960; Di Bartolo, Núñez-Dey, and Bendejú-Prieto, 1962). The 2-OS interval measured from the aortic component of the second heart sound to the opening snap has been used for evaluation of the degree of severity of the stenotic lesion. It is generally felt that as the severity of mitral stenosis increases, the 2-OS interval decreases (Kelly, 1955; Bayer *et al.*, 1956; Steinzeig *et al.*, 1957; Proctor *et al.*, 1958; Donnelly *et al.*, 1959; Rich, 1959; Di Bartolo *et al.*, 1962). Therefore, the 2-OS interval has been frequently cited in the clinical evaluation of mitral valvular disease. However, if a patient does not have an opening snap, this measurement cannot be made.

It is the purpose of this work to demonstrate that this same 2-OS interval (isometric relaxation of the left ventricle) as measured in the phonocardiogram can be accurately determined in the absence of the opening snap by use of the apex cardiogram.

SUBJECTS AND METHOD

Forty-three patients with mitral valvular disease were studied. Of these, 18 had mitral stenosis (MS), 13 had mitral regurgitation (MR), and 12 had combined lesions (MS-MR). In 20 patients the diagnosis was confirmed by cardiac catheterization or by operation. Five were proved at necropsy. The remaining 23 were included on accepted clinical data and radiological and electrocardiographic findings. A control group of 40 subjects was chosen on the basis of a negative history and normal physical examination.

An Electronics for Medicine, DR-8, multichannel photographic recorder was used to obtain the simultaneous phonocardiogram (PCG) at the mitral area, the apex cardiogram (ACG), and the electrocardiogram (EKG). In about half the cases, the PCG and ACG were recorded simultaneously on a Sanborn Twin-Beam phonocardiograph. The Sanborn microphone No. 62-1500-C-10 was used in all cases. A pulse wave crystal microphone (Sanborn No. 374) was used to obtain the ACG: details of the technique of recording it have been described previously (Benchimol *et al.*, 1960; Benchimol, Dimond, and Carson, 1961; Dimond and Benchimol, 1961).

In the analysis of tracings, special attention was given to the period of isometric relaxation. This interval is represented by the 2-OS interval in the phonocardiogram of patients with mitral valve disease when the opening snap is present. This time interval from the aortic component of the second heart sound to the O-point in the apex cardiogram was measured and designated the 2-O interval (Benchimol and Legler, 1962) (Fig. 1).

* This work was supported in part from NIH Research Grant No. H-5575, NIH Graduate Training Grant HTS-5513, and by the Timkin-Sturgis Cardiovascular Research Grant.

FIG. 1.—Normal subject. ACG and PCG demonstrating the measurement of the 2-O interval. Time lines are 0.1 second apart.

FIG. 2.—Mitral stenosis. ACG and PCG demonstrating the measurements of the 2-O and 2-OS intervals. Note the SFW in the LV-ACG and the RFW in the RV-ACG compatible with tricuspid regurgitation in combination with the mitral stenosis. Time lines are 1 second apart.

FIG. 3.—Mitral regurgitation. ACG and PCG showing the 2-O interval measurement in a patient with mitral valvular disease without an opening snap. Note the third heart sound is coincident with the peak of the RFW in the ACG. Time lines are 0.04 second apart.

FIG. 4.—Mitral stenosis and regurgitation. ACG and PCG with the measurement of the 2-O and 2-OS intervals indicated. Note the opening snap coinciding with the O-point and the third heart sound occurring with the peak of the RFW in the ACG. Time lines are 0.04 second apart.

FIG. 4.

The reported intervals represent the mean values of measurements made in three consecutive cardiac cycles. The paper speed was 75 mm. per second in all tracings.

The following abbreviations have been employed throughout this study: 1, first heart sound; 2, second heart sound; 3, third heart sound; 4, fourth heart sound; SM, systolic murmur; DM, diastolic murmur; OS, opening snap; MA, mitral area; TA, tricuspid area; LF, low frequency; MF, medium frequency; LV-ACG, left ventricle ACG; RV-ACG, right ventricle ACG; "a", atrial wave in ACG; O, O-point in ACG which marks opening of mitral valve; E, ejection point in ACG; RFW, rapid filling wave; SFW, slow filling wave; and CT, carotid tracing.

RESULTS

The control group of 40 normal subjects revealed a 2-O interval that varied from 0.02 to 0.09 second with an average of 0.06 second (± 0.017)* (Fig. 1). Eighteen patients with MS had a 2-O interval from 0.05 to 0.11 second with an average of 0.08 second (± 0.017). Of these, nine had an opening snap with a 2-OS interval that averaged 0.08 second (± 0.014) and a range of 0.06 to 0.10 second (Fig. 2). Mitral regurgitation was the only lesion in 13 patients. The 2-O interval varied from 0.03 to 0.12 second with an average of 0.07 second (± 0.026) (Fig. 3). Twelve patients had a combined lesion of mitral stenosis and regurgitation. The range for the 2-O interval was from 0.5 to 0.10 second, the average being 0.07 second (± 0.016). The 2-OS interval in the 6 patients with an opening snap varied from 0.05 to 0.09 second with an average of 0.07 second (± 0.013) (Fig. 4).

FIG. 5.—Frequency distribution of the 2-O interval in the group of normal subjects and in patients with mitral valvular disease. Note there is considerable overlap between the various groups.

When all 43 patients with mitral valve disease were combined, the 2-O interval averaged 0.08 second (± 0.02) with a range of 0.03 to 0.12 second (Fig. 5). Fifteen cases with an opening snap had a range of 2-OS interval from 0.05 to 0.10 second and an average of 0.08 second (± 0.012) (Fig. 6). The standard deviation of the difference between the 2-O and the 2-OS intervals was ± 0.008 . The value for "r" was +0.92.

* All the numbers in parentheses preceded by a $\pm$ sign represent the standard deviation.

DISCUSSION

The 2-OS interval representing the period of isometric relaxation has been studied by various authors in patients with mitral valvular disease and its usefulness has been repeatedly emphasized (Margolies and Wolferth, 1932; Messer *et al.*, 1951; Julian and Davies, 1957; Mounsey, 1953; Wells, 1954; Kelly, 1955; Bayer *et al.*, 1956; Steinzeig *et al.*, 1957; Wells, 1957; Di Perri and Fabrizi, 1958; Proctor *et al.*, 1958; Donnelly *et al.*, 1959; Rich, 1959; Muiesan *et al.*, 1960). However, this measurement can only be obtained in patients in whom an opening snap is present. From our data it is evident that the simultaneous recording of the apex cardiogram with the phonocardiogram

FIG. 6.—Graph showing the 2-O and 2-OS intervals plotted against each other in 13 patients with mitral valvular disease with an opening snap. There is good correlation with an “*r*” value +0.92 and the standard deviation of the difference ± 0.008 . MS=mitral stenosis. MR=mitral regurgitation.

FIG. 7.—Mitral stenosis. ACG and PCG with pulmonary wedge pressure curve. The O-point in the ACG coincides with the peak of the “*v*” wave in the pulmonary wedge curve indicating the opening of the mitral valve. Note the absence of an openingsnap in the PCG. However, the 2-O interval provides an accurate measurement of the period of isometric relaxation.

provides a simple and accurate method of studying this interval in all subjects regardless of the presence or absence of the opening snap (Fig. 7). The fact that the O-point in the apex cardiogram coincides with the opening snap in the phonocardiogram and with the peak of the “*v*” wave in the pulmonary “wedge” or left atrial pressure curve provides documentary evidence that the O-point does occur simultaneously with other graphic events usually associated with opening of the mitral valve (Fig. 7). In 15 patients with an opening snap there was good correlation between the 2-OS and the 2-O intervals with an “*r*” value of +0.92 and a standard deviation of the difference of ± 0.008 . Thus, when an opening snap is not present, the 2-O interval can be measured instead of the 2-OS interval.

SUMMARY

The period of isometric relaxation of the left ventricle was studied in a group of 40 normal subjects and 43 patients with mitral valvular disease by the use of the apex cardiogram. This was done by measuring the interval from the aortic component of the second heart sound to the O-point

in the apex cardiogram. This was designated the 2-O interval. There was good correlation between the 2-O and the 2-OS intervals in the mitral valvular disease group. Therefore, it is suggested that in the absence of an opening snap this same interval can be measured with the same degree of accuracy.

We wish to thank Miss Ellen Wright and Mrs. Alexine Carvalho for their technical assistance.

REFERENCES

- Bayer, O., Loogen, F., and Wolter, H. H. (1956). *Amer. Heart J.*, **51**, 234.
 Benchimol, A., Dimond, E. G., and Carson, J. C. (1961). *Amer. Heart J.*, **61**, 485.
 —, —, Waxman, D., and Shen, Y. (1960). *Amer. Heart J.*, **60**, 417.
 —, and Legler, J. F. (1962). *Clin. Res.*, **10**, 71.
 Craige, E. (1957). *New Engl. J. Med.*, **257**, 650.
 Dack, S., Bleifer, S., Grishman, A., and Donoso, E. (1960). *Amer. J. Cardiol.*, **5**, 815.
 Di Bartolo, G., Núñez-Dey, D., and Bende-zú-Prieto, J. (1962). *Amer. J. Cardiol.*, **10**, 93.
 Dimond, E. G., and Benchimol, A. (1961). *Calif. Med.*, **94**, 139.
 Di Perri, T., and Fabrizi, G. (1958). *Cardiologia*, **33**, 97.
 Donnelly, G. L., Maha, G. E., and Orgain, E. S. (1959). *J. thorac. Surg.*, **37**, 200.
 Julian, D., and Davies, L. G. (1957). *Brit. Heart J.*, **19**, 486.
 Kelly, J. J., Jr. (1955). *Amer. J. Med.*, **19**, 862.
 Leo, T., and Hultgren, H. (1959). *Medicine (Baltimore)*, **38**, 85.
 Margolies, A., and Wolferth, C. C. (1932). *Amer. Heart J.*, **7**, 443.
 Messer, A. L., Counihan, T. B., Rappaport, M. B., and Sprague, H. B. (1951). *Circulation*, **4**, 576.
 Mounsey, P. (1953). *Brit. Heart J.*, **15**, 135.
 Muiesan, G., Innocenti, P. F., Cinotti, G., and Toso, M. (1960). *Folia cardiol. (Milano)*, **19**, 445.
 Nixon, P. G. F., Wooler, G. H., and Radigan, L. R. (1960). *Brit. Heart J.*, **22**, 395.
 Proctor, M. H., Walker, R. P., Hancock, E. W., and Abelman, W. H. (1958). *Amer. J. Med.*, **24**, 861.
 Rich, C. B. (1959). *Canad. med. Ass. J.*, **81**, 800.
 Steinzeig, S. M., Pinsky, S. T., Alimurung, M. M., and Dimond, E. G. (1957). *Amer. Heart J.*, **53**, 735.
 Wells, B. (1954). *Brit. Heart J.*, **16**, 261.
 — (1957). *Brit. med. J.*, **1**, 551.