Comparison of Ejection Fraction and Zonal Mean Velocity of Myocardial Fiber Shortening

By F. K. Nakhjavan, M.D., Gangaih Natarajan, M.B.B.S., and Harry Goldberg, M.D.

SUMMARY
To determine the extent of cardiac involvement until a diminished ejection fraction (EF) is present, zonal mean velocity of circumferential fiber shortening (Vcf) was measured from the left ventriculogram in 36 patients. The longitudinal axis (apex to mid-point of the aortic valve plane) in right anterior oblique view was divided into four equal parts by three perpendicular chords. Zonal Vcf and percent shortening along the proximal, middle and distal chords were measured. The results of this study indicate that a normal EF is frequently associated with a reduced Vcf in one or even two zones. A reduced EF is generally accompanied by a diminished Vcf in all three zones of the heart. In addition, a close correlation was found between zonal Vcf and percent shortening. Hence the latter, which is much simpler to measure, can be used instead of Vcf. Ejection fraction as a measure of myocardial performance is not as sensitive as Vcf, especially in hearts with asynchrony of contraction.

EJECTION FRACTION (EF) is commonly used as a measure of myocardial performance. It is a common finding, however, that certain zones of the heart may be hypokinetic or akinetic while EF remains normal. To discover the extent of myocardial malfunction before EF is affected, another measure of myocardial performance, mean velocity of circumferential fiber shortening (Vcf) in three different zones of the heart along the major axis, was measured. The results of this study indicate that a normal EF may frequently be associated with a reduced Vcf in one or even two zones of the heart.

Material and Method
Thirty-six patients referred to us for cardiac catheterization and angiographic studies form the basis of this study. Eight patients had normal cardiac hemodynamic and angiographic findings. Of the remaining patients, eight had prolapsing mitral leaflet syndrome; 17 had coronary artery disease; one had primary myocardial disease; and two patients had angina with normal coronary arteries but abnormal myocardial lactate metabolism. Cardiac catheterization and angiographic studies were performed in the post-absorptive state after premedication with 50 mg diphenhydramine hydrochloride and 75 mg sodium pen-tobarbital intramuscularly one hour prior to the studies. Left ventriculograms at 60 frames per second were obtained in the 30 degree right anterior oblique view by injection of 40–50 ml of methylglucamine diatrizoate (Renografin 76) into the left ventricle under 100–150 pounds of pressure per square inch. Ejection fraction was measured according to a modified Greene’s method using apex to mid-point of the aortic valve plane as the longitudinal axis. For measurement of the zonal Vcf, the longitudinal axis of the projected cine image was divided into four equal parts by three perpendicular chords (fig. 1). Zonal Vcf along the proximal, middle and distal chords was measured using the method of Karliner et al. from the difference between the end-diastolic and end-systolic circumferences minus 50 msec (average isovolumic contraction time), divided by the ejection time and diastolic circumference. The ejection time was measured as the interval between end diastole and end ejection. End diastole was determined from the electrocardiogram on cine trace of the left ventriculogram. End ejection was defined as the maximal inward excursion (shortening) of the ventricular wall. No patients with angiographically proven significant mitral regurgitation, ventricular aneurysm (outpouching) or extrasystoles during the left ventriculography were included in this series. All the patients were in sinus rhythm. EF and Vcf were measured in two successive beats using the early cardiac cycles after the injection. The mean difference in Vcf between the two measurements was 0.09; circumferences (circ)/sec (range 0.01–0.28) in the proximal zone, 0.15 circ/sec (range 0.00–0.29) in the middle zone and 0.15 circ/sec (range 0.02–0.29) in the distal zone. The mean difference in EF between the two measurements was 0.03 (range 0–0.06). Zonal Vcf was also correlated with percent shortening in the corresponding zones. An ejection fraction of 0.63 was used as the lower limit of normal in this study since it was the lowest value obtained in the normal group of the present series (see Discussion for further explanation).

Results
Patients with Normal Zonal Vcf (table 1, fig. 2)
In eight patients (group 1) with no detectable cardiac disease, mean EF was 0.75 (range 0.63–0.87). Mean zonal Vcf in proximal, middle and distal zones of the heart was 1.46 circ/sec (range 1.13–2.08), 1.71

From the Cardiac Hemodynamic Unit and Cardio-Pulmonary-Renal Laboratories, Albert Einstein Medical Center, Philadelphia, Pennsylvania.
Dr. Natarajan is a National Institutes of Health trainee in Cardiology.
Received September 6, 1974; revision accepted for publication March 14, 1975.
circ/sec (range 1.20-2.68) and 2.10 circ/sec (range 1.64-3.48), respectively. Percent myocardial shortening in the respective zones was 39.4 (range 31-52), 45.4 (range 35-59) and 57.9 (range 41-76). Four additional patients (group II) — two with insignificant coronary artery disease and two with prolapsing mitral leaflet syndrome — were included with the normal subjects since their EF, zonal Vcf and percent shortening were in the range obtained for patients with normal findings.

Patients with Abnormal Vcf (table 1, fig. 2)

Group I: diminished Vcf in one zone. There were eight patients in this group. In five patients Vcf was diminished in the distal zone and in three in the proximal zone. EF was normal in all. Group II: diminished Vcf in two zones. There were five patients in this group. Zonal Vcf was diminished in the middle and distal zones in three patients, in the proximal and middle zones in one, and in the proximal and distal zones in one. EF was diminished in two and normal in three. Group III: diminished Vcf in three zones. There were 11 patients in this group. EF was diminished in all.

Comparison Between Zonal Vcf, Percent Myocardial Shortening and Left Ventricular End-diastolic Pressure (LVEDP)

There was a strong correlation (r = 0.91) between zonal Vcf and percent myocardial shortening (fig. 3). There was no correlation between LVEDP, Vcf and EF. However of seven patients with an elevated LVEDP, one was in group I (diminished Vcf in one zone), two were in group II (diminished Vcf in two zones), and four were in group III (diminished Vcf in three zones). There was no case with a diminished EF or an elevated LVEDP in whom Vcf was normal in all three zones.


Table 1

Patients with Normal and Abnormal Vcf.

<table>
<thead>
<tr>
<th>Case no.</th>
<th>Diagnosis</th>
<th>Proximal Vcf.</th>
<th>% Short</th>
<th>Middle Vcf.</th>
<th>% Short</th>
<th>Distal Vcf.</th>
<th>% Short</th>
<th>EF</th>
<th>LVEDP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Normal</td>
<td>1.25</td>
<td>31</td>
<td>1.60</td>
<td>39</td>
<td>1.64</td>
<td>41</td>
<td>0.68</td>
<td>12</td>
</tr>
<tr>
<td>2</td>
<td>Normal</td>
<td>1.13</td>
<td>37</td>
<td>1.28</td>
<td>42</td>
<td>1.70</td>
<td>56</td>
<td>0.70</td>
<td>6</td>
</tr>
<tr>
<td>3</td>
<td>Normal</td>
<td>1.44</td>
<td>43</td>
<td>1.20</td>
<td>35</td>
<td>2.42</td>
<td>70</td>
<td>0.72</td>
<td>7</td>
</tr>
<tr>
<td>4</td>
<td>Normal</td>
<td>1.86</td>
<td>42</td>
<td>2.68</td>
<td>59</td>
<td>3.48</td>
<td>76</td>
<td>0.87</td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>Normal</td>
<td>2.08</td>
<td>32</td>
<td>1.43</td>
<td>36</td>
<td>1.65</td>
<td>54</td>
<td>0.63</td>
<td>7</td>
</tr>
<tr>
<td>6</td>
<td>Normal</td>
<td>1.24</td>
<td>36</td>
<td>1.49</td>
<td>43</td>
<td>1.67</td>
<td>48</td>
<td>0.72</td>
<td>13</td>
</tr>
<tr>
<td>7</td>
<td>Normal</td>
<td>1.44</td>
<td>40</td>
<td>1.56</td>
<td>51</td>
<td>1.84</td>
<td>51</td>
<td>0.78</td>
<td>12</td>
</tr>
<tr>
<td>8</td>
<td>Normal</td>
<td>1.22</td>
<td>34</td>
<td>2.12</td>
<td>58</td>
<td>2.42</td>
<td>67</td>
<td>0.86</td>
<td>7</td>
</tr>
<tr>
<td>9</td>
<td>PML</td>
<td>1.49</td>
<td>36</td>
<td>1.87</td>
<td>44</td>
<td>2.25</td>
<td>50</td>
<td>0.76</td>
<td>3</td>
</tr>
<tr>
<td>10</td>
<td>PML</td>
<td>1.16</td>
<td>33</td>
<td>1.98</td>
<td>56</td>
<td>2.29</td>
<td>65</td>
<td>0.85</td>
<td>7</td>
</tr>
<tr>
<td>11</td>
<td>CAD</td>
<td>1.15</td>
<td>31</td>
<td>2.02</td>
<td>54</td>
<td>2.60</td>
<td>69</td>
<td>0.81</td>
<td>6</td>
</tr>
<tr>
<td>12</td>
<td>CAD</td>
<td>1.20</td>
<td>25</td>
<td>1.61</td>
<td>33</td>
<td>2.76</td>
<td>56</td>
<td>0.63</td>
<td>6</td>
</tr>
</tbody>
</table>

Normal

Abnormal

Group I

1 zone

1 PML | 1.65 | 44 | 1.90 | 53 | 1.49* | 42 | 0.81 | 8
2 CAD | 1.30 | 39 | 1.40 | 42 | 1.58* | 47 | 0.70 | 6
3 PML | 1.82 | 48 | 1.22 | 33 | 1.25* | 33 | 0.65 | 8
4 Angina & NCA | 1.20 | 39 | 1.40 | 45 | 1.44* | 47 | 0.77 | 10
5 CAD | 0.73* | 25 | 1.34 | 47 | 1.64 | 62 | 0.74 | 7
6 CAD | 1.00* | 35 | 1.86 | 62 | 2.13 | 71 | 0.90 | 16
7 CAD | 0.77* | 22 | 1.57 | 44 | 1.82 | 52 | 0.74 | 4
8 Angina & NCA | 1.30 | 42 | 1.21 | 39 | 1.14* | 37 | 0.65 | 6

Group II

2 zones

1 PML | 1.26 | 46 | 1.15* | 43 | 1.40* | 51 | 0.73 | 12
2 CAD | 0.70* | 21 | 1.36 | 41 | 1.30* | 39 | 0.72 | 8
3 CAD | 1.06* | 32 | 0.69* | 41 | 1.76 | 53 | 0.73 | 24
4 PML | 1.21 | 36 | 0.66* | 20 | 1.04* | 32 | 0.43 | 3
5 CAD | 1.19 | 28 | 0.38* | 13 | 0.86* | 20 | 0.34 | 25

Group III

3 zones

1 PML | 1.05 | 25 | 1.17 | 19 | 1.40 | 15 | 0.59 | 5
2 PML | 1.03 | 23 | 1.12 | 20 | 1.33 | 25 | 0.58 | 5
3 PMD | 0.88 | 30 | 0.94 | 10 | 0.28 | 8 | 0.54 | 17
4 CAD | 0.57 | 13 | 0.69 | 15 | 1.24 | 24 | 0.43 | 10
5 CAD | 0.74 | 21 | 0.74 | 17 | 0.60 | 17 | 0.37 | 9
6 CAD | 0.90 | 24 | 0.94 | 29 | 0.65 | 20 | 0.59 | 14
8 CAD | 0.72 | 23 | 0.58 | 18 | 0.80 | 25 | 0.38 | 14
9 CAD | 0.73 | 25 | 0.65 | 19 | 0.53 | 15 | 0.34 | 7
10 CAD | 0.84 | 22 | 0.83 | 20 | 1.04 | 25 | 0.43 | 7
11 CAD | 1.05 | 30 | 0.37 | 10 | 0.29 | 8 | 0.30 | 8

*Area with diminished Vcf.

Abbreviations: Vcf = zonal mean velocity of circumferential fiber shortening; % short = percent shortening; EF = ejection fraction; LVEDP = left ventricular end-diastolic pressure; CAD = coronary artery disease; PMD = primary myocardial disease; PML = prolapsing mitral leaflet syndrome; NCA = normal coronary arteries.

Discussion

The work of several investigators has shown that EF as a measure of myocardial performance is less sensitive than Vcf. The present study is basically in agreement with the results of these investigators. When Vcf was diminished in one zone, EF remained normal. The location of the zones with reduced Vcf seemed to have no influence on EF. When Vcf was diminished in all three zones, EF was reduced in all the patients. However, when Vcf was diminished in two zones, EF was normal (three patients) or reduced (two patients). Hence a reduced EF does not usually occur unless the contractility is diminished in at least two zones of the heart. In this study, we have used 0.63 as the lower limit of EF. Using 0.56 as the lower limit of EF (which is widely used in the literature) would make EF even less sensitive since four patients in group III (diminished Vcf in all three zones) would then have low normal EF. Since coronary artery disease commonly affects the contractile pattern of the heart in a nonuniform manner, the value of determining Vcf in multiple zones is evident. Indeed this point is suggested by proponents of Vcf as a measure of myocardial contractility. Thus determination of zonal myocardial shortening and/or Vcf would be of particular importance in the assessment of myocardial abnormalities following saphenous vein bypass operations.

In the present study, comparison of the zonal Vcf with percent shortening revealed a correlation coe-
ficulties in the present study, which undoubtedly is a source of error, is the determination of the exact time of end systole and end diastole in each zone of the heart. Since in a heart with asynchrony of contraction the shortening in each zone may vary, the true ejection time for that particular zone may not necessarily be the same as the ejection time for the whole heart. In the present study, however, ejection time could not be reliably determined in each zone and hence the extent of shortening was measured for the whole heart. It would be reasonable to assume that if such measurements could be determined in each zone of the heart, V_{ef} would be even more sensitive as a measure of zonal myocardial contractility.

In conclusion, it may be stated that EF is not a sensitive measure of myocardial performance as compared to V_{ef}. Determination of V_{ef} in various zones of the heart yields valuable information in regard to myocardial performance in hearts with asynchrony of contraction. A strong correlation exists between zonal V_{ef} and percent shortening; hence the latter, which is much simpler to measure, can be used as a measure of myocardial performance.

References


Figure 3

Relationship between zonal V_{ef} (ordinate) and percent shortening (abscissa).
Comparison of ejection fraction and zonal mean velocity of myocardial fiber shortening.
F K Nakhjavan, G Natarajan and H Goldberg

*Circulation*. 1975;52:264-267
doi: 10.1161/01.CIR.52.2.264

*Circulation* is published by the American Heart Association, 7272 Greenville Avenue, Dallas, TX 75231
Copyright © 1975 American Heart Association, Inc. All rights reserved.
Print ISSN: 0009-7322. Online ISSN: 1524-4539

The online version of this article, along with updated information and services, is located on the World Wide Web at:
http://circ.ahajournals.org/content/52/2/264

Permissions: Requests for permissions to reproduce figures, tables, or portions of articles originally published in *Circulation* can be obtained via RightsLink, a service of the Copyright Clearance Center, not the Editorial Office. Once the online version of the published article for which permission is being requested is located, click Request Permissions in the middle column of the Web page under Services. Further information about this process is available in the Permissions and Rights Question and Answer document.

Reprints: Information about reprints can be found online at: http://www.lww.com/reprints

Subscriptions: Information about subscribing to *Circulation* is online at: http://circ.ahajournals.org//subscriptions/