

Noninvasive Assessment of the Cardiovascular System

Diagnostic Principles and Techniques

Edited by
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CHAPTER 35

Value of the Radial Segmental Ejection Fraction in the Assessment of Regional Left Ventricular Function in the Radionuclide Ventriculogram

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Assessment of regional left ventricular function from the radionuclide ventriculogram is generally based on visual evaluation of the sequential images obtained in the form of a film.¹ Facilitation of visual evaluation may be achieved through various methods of information processing, such as creation of a stroke volume, ejection fraction or gradient image, as well as through display of amplitude or phase distribution.²⁻⁴ Computerized, quantitative evaluation is desirable to provide objective data on changes in regional ventricular function and to eliminate, as nearly as possible, intraobserver and interobserver variability. Accordingly, we have developed a method in which the regional ejection fraction is calculated from the count rate in radially ordered segments.⁵ This study was undertaken to analyze the value of the data thus obtained on regional ventricular function, expressed in terms of sensitivity and specificity.

PATIENTS AND METHODS

Radionuclide ventriculograms were obtained from 35 patients within 24 hours of contrast ven-

triculography. Regional wall motion in contrast ventriculograms was assessed from the percent left ventricular hemiaxis shortening in the 30° RAO and 60° LAO projections, and designated as normokinetic, hypokinetic and akinetic.⁶ Of 19 patients with coronary artery disease, seven had hypokinesis and 12 akinesis. Sixteen healthy subjects served as controls.

Radionuclide ventriculograms were obtained after equilibration of 15 to 20 mCi ($5.5-7.4 \times 10^8$ Bq) technetium 99m in vivo-labeled erythrocytes. Activity was recorded with an Anger camera (LEM, Searle-Siemens) employing a high sensitivity parallel-hole collimator in the MLA0 projection. Computerized analysis was achieved with a DEC processor (PDP 11/34) at 21 frames per cardiac cycle on a 64×64 word matrix (for details, see reference 5). In the method proposed, determination of the regional ejection fraction was carried out after designation of end diastolic (ED) and end systolic (ES) regions of interest (ROI) as well as subtraction of a paracardially measured background. Designation of left ventricular (LV) wall contours was performed only manually since our earlier investigations demonstrated that manual designation of the LV ROIs

enabled a more exact determination of the global left ventricular ejection fraction than the computer programs used for automatic edge detection (Table 35-1). For assessment of the regional ejection fraction the ED image within the LV ROI was divided into 12 radially ordered sectors of 30° of arch each (Figure 35-1), consecutively numbered beginning at 12 o'clock such that the segments correspond with the posterolateral, apicoinferior and anteroseptal regions (Figures 35-2 through 35-4). The center point of the left ventricular area is automatically designated as the geometric center of a rectangle superimposed on the ED ROI. In each of the 12 segments, the EF is calculated from the ED and ES count rate, where

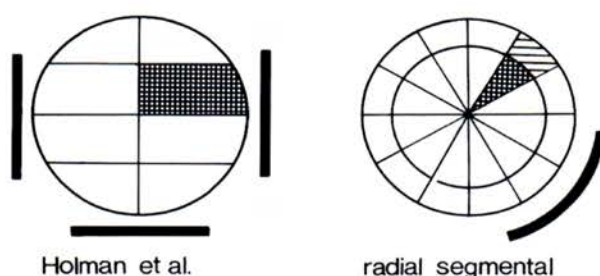


Figure 35-1 Comparison of the method for determination of the regional ejection fraction suggested by Holman and colleagues with that of the radial segmental method. The method proposed by Holman et al is based on calculation of the regional ejection fraction in eight nearly rectangular fields ordered about the long axis of the left ventricle without additional designation of the end systolic region of interest and employment of an interpolative process for background correction. In the method proposed in our study, determination of the regional ejection fraction is carried out after designation of end diastolic and end systolic region of interest, which is divided into 12 radially ordered segments; background correction is carried out with respect to paracardially measured activity.

the ES count rate is recorded from within the end systolically determined LV ROI. No correction for systolic shift of the center point was carried out.

The value of the scintigraphic assessment of the regional ventricular function was analyzed with respect to classification of the relationship of the latter at the 1-sigma, 1.5-sigma and 2-sigma limits with that of contrast ventriculography. Accordingly, scintigraphic radial segmental ejection fraction was defined as "diminished" as compared with the respective sigma values of the healthy controls. A "markedly diminished" radial segmental ejection fraction was considered to be present if its value was outside the respective limits of patients with hypokinesis. In patients with hypokinesis, the sensitivity was defined as the number of patients with diminished radial segmental ejection fractions in at least two adjacent segments divided by the number of patients with hypokinesis. In patients with akinesis, the sensitivity was calculated to be the number of patients with "markedly diminished" radial segmental ejection fractions divided by the number of patients with contrast ventriculographically documented akinesis. The specificity was derived as the percent inclusion of patients with normal radial segmental ejection fractions in the group of healthy controls.

RESULTS

The normal values for the radial segmental left ventricular ejection fraction, as obtained from 16 healthy control subjects, can be seen in Figure 35-2. Segments 1, 11, and 12 correspond with the LV inflow and outflow tract. The mean values for

Table 35-1
Comparison of the Relationship Between the Contrast Angiographically Determined Left Ventricular Ejection Fraction with That of Three Different Scintigraphic Methods in 103 Patients

	Correlation Coefficient	Inclination	Intercept	Mean Standard Deviation
Manual	$r = 0.95$	0.97	0.09	± 5.3
1st derivative	$r = 0.90^*$	1.07	- 5.20	± 8.6
2nd derivative	$r = 0.82^*$	0.98	1.51	± 10.8

* $p < 0.05$

The scintigraphic methods are, as indicated, manual designation of the end diastolic and end systolic left ventricular region of interest and automatic edge detection using the first and second derivatives (see reference 5). Manual designation of the left ventricular region of interest yielded a better correlation than the automatic methods.

the radial segmental ejection fraction in segments 2 through 10 ranged from $55 \pm 12\%$ to $83 \pm 8\%$. The mean values in the apicoinferior segments were higher than those of the posterolateral and antero-septal segments (Figure 35-2). The comparison of the radial segmental left ventricular ejection fraction and the percent hemi-axis shortening in the contrast ventriculogram is shown in Figures 35-3 and 35-4. In patients with anteroapical hypokinesis, that is, with significant reductions in the percent hemi-axis shortening in the apical or anterior regions to 13% and 23% respectively, the scintigraphic segments 5 to 10 showed a significantly diminished radial segmental ejection fraction of 39% to 62% ($p < 0.005$, Figure 35-3) as compared with normal.

In patients with anteroapical akinesis, that is, near absence of hemi-axis shortening in the respective regions, the radial segmental ejection fraction in the corresponding anterior and apical segments averaged between 15% and 22% (Figure 35-4). In these patients, the radial segmental ejection fraction in normokinetic posterolateral regions was also significantly diminished at 45% (Figure 35-4).

The values calculated for the sensitivity and specificity are a function of the chosen lower limit (Table 35-2). If detection of regional ventricular function impairment is based on the 1-sigma limit, the sensitivity in patients with hypokinesis and akinesis is 100%, albeit with a low specificity of 63%. Based on the 1.5-sigma limit, the sensitivity

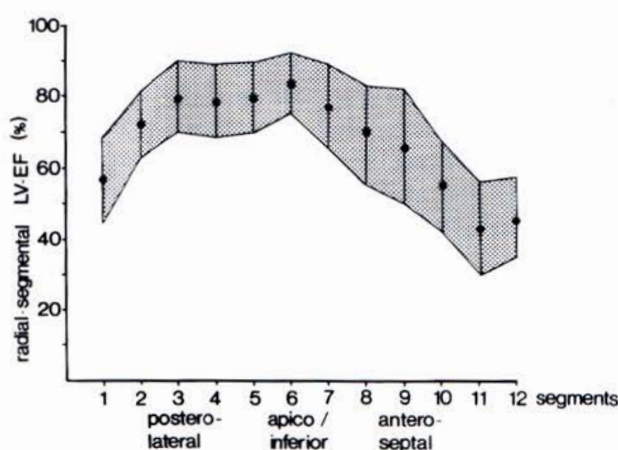


Figure 35-2 Normal values (mean and standard deviation) for radial segmental ejection fraction as determined in 16 healthy control subjects. Segments 1, 11, and 12 correspond to the left ventricular inflow and outflow tracts. The mean value of the apicoinferior region is higher than that of the posterolateral and antero-septal regions.

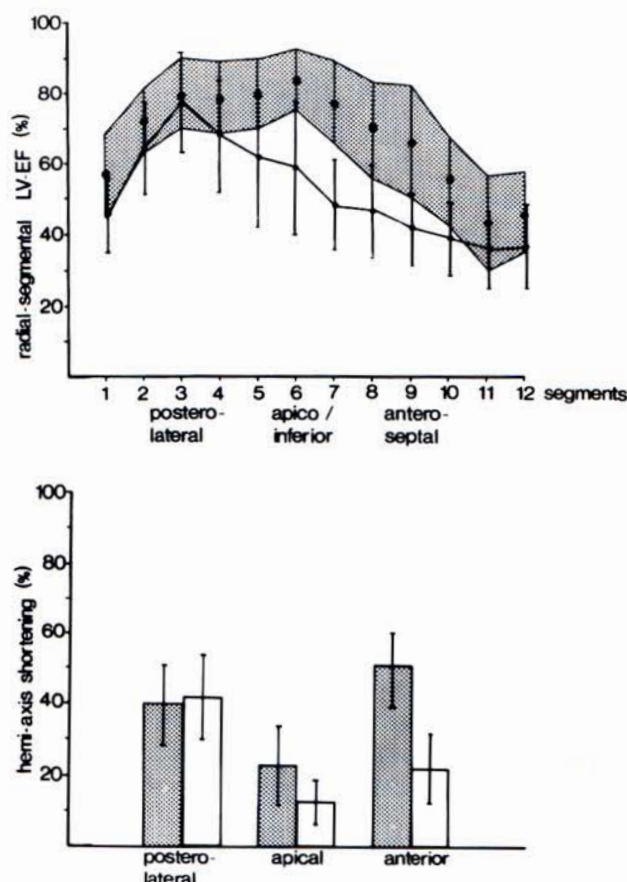


Figure 35-3 Comparison of radial segmental left ventricular ejection fraction (above) with contrast ventriculographically determined percent hemi-axis shortening (below) in patients with anteroapical hypokinesis ($n = 7$). As compared with normal ranges (darkened columns), the hemi-axis shortening in the anterior and apical regions is significantly diminished. In comparison with the normal range (darkened area), segments 5 to 10 show a significantly diminished radial segmental ejection fraction to an average of 39% to 62%.

in patients with hypokinesis was lowered to 86%; that of patients with akinesis remained at 100% and the specificity increased to 88%. On choosing the 2-sigma lower limit, the sensitivities of patients with hypokinesis and akinesis were rendered 57% and 83%, respectively, and the specificity reached 100% (Table 35-2).

DISCUSSION

The results of this study show that a diminished radial segmental ejection fraction is associated with impaired regional wall motion. Quantitatively, the mean values for the radial segmental ejection fractions in patients with akinesis were more markedly diminished than those in patients with

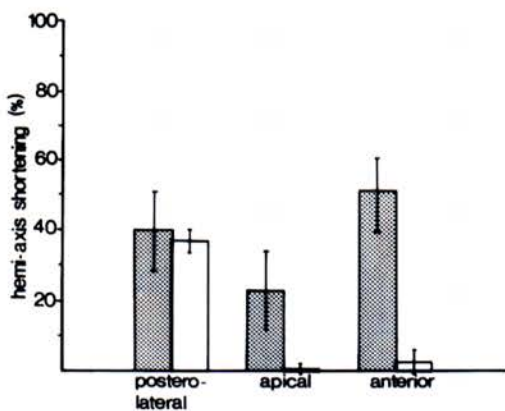
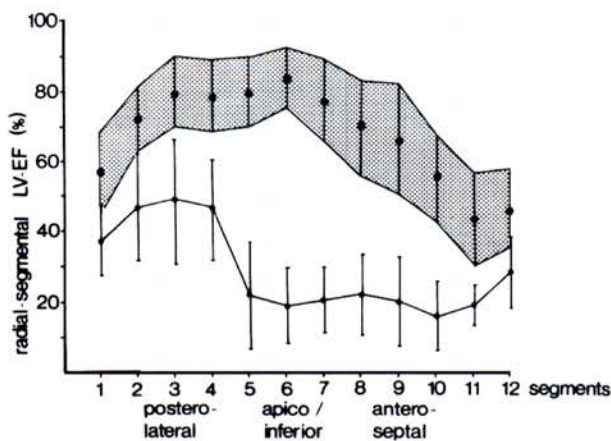


Figure 35-4 Comparison of radial segmental left ventricular ejection fraction (above) with contrast ventriculographically determined percent hemi-axis shortening (below) in patients with anteroapical akinesis ($n = 12$). The radial segmental left ventricular ejection fraction is significantly diminished to an average of 15% to 22% in the anteroapical region and to a lesser degree (45%) in the posterolateral region as well (normal range shown by darkened area). The lower panel shows the mean percent hemi-axis shortening of the corresponding segments as determined by contrast ventriculography (normal ranges shown as darkened columns).

hypokinesia (Figures 35-3 and 35-4). Analysis of the value of the radial segmental ejection fraction in the detection of regional wall motion impairment with respect to the 1-sigma and 1.5-sigma limits yielded high sensitivity but with compromised specificity (Table 35-2). A clinically relevant decision, ie, with high specificity, was enabled by designation of a 2-sigma lower limit but only at the cost of a decreased sensitivity, especially in patients with hypokinesia (Table 35-2). In spite of some methodologic differences, these findings are in good agreement with those obtained from the determination of regional ejection

Table 35-2
Sensitivity and Specificity of the Radial Segmental Left Ventricular Ejection Fraction in the Detection of Regional Ventricular Function Impairment

Lower Limit of Normal	Sensitivity		Specificity
	<i>Hypokinesia</i>	<i>Akinesia</i>	
1 sigma	100%	100%	63%
1.5 sigma	86%	100%	88%
2 sigma	57%	83%	100%

The values are shown with respect to choice of the 1-sigma, 1.5-sigma and 2-sigma lower limits.

fraction as proposed by Holman and co-workers^{2,3,7} (Figure 35-1).

Comparison of the scintigraphically determined ejection fraction with that calculated from hemi-axis shortening in the contrast ventriculogram is problematic, since the regional ejection fraction derived from volume changes is considered with respect to one-dimensional length changes. The ideal comparison between invasively and noninvasively determined regional ejection fractions would entail the use of sophisticated computerized methods.⁸ The frequent finding of normal regional ejection fractions in patients with hypokinesia (Figure 35-3) can best be explained on the basis of fundamental differences between the regional ejection fraction and regional wall motion. Similarly, the finding of regional ejection fractions of up to 10% in association with akinesia (Figure 35-4) appears due to superimposition of portions of still synergic walls. This appears to be especially true for the observation of diminished regional ejection fraction in posterolateral segments in patients with extensive anterior infarction, which can be accounted for by superimposition of the akinetic portion of the anterior wall into a synergic posterolateral wall (Figure 35-4).

Thus, for detection of only limited degrees of ventricular function impairment, analysis of wall motion is more useful than the regional ejection fraction. Prerequisite, however, is an adequate number of projections. The advantage of the parameter of the regional ejection fraction is that it can be obtained from a single projection. This enables imaging as necessary for studies with short acquisition time, eg, during exercise testing or monitoring of pharmacologic interventions.

SUMMARY

To assess regional ventricular function in the radionuclide ventriculogram, the region of interest of the left ventricle was divided into 12 radially ordered segments in which the radial segmental ejection fraction was calculated from the end diastolic and end systolic count rates and compared with the percent hemi-axis shortening of the contrast ventriculogram. In the 35 patients studied, the normal values ranged from $55 \pm 12\%$ in the anteroapical region to $83 \pm 8\%$ in the apicoinferior region. In patients with anteroapical hypokinesis, the radial segmental ejection fractions in the respective segments were between 39% and 62%, and in those with anteroapical akinesis the values were diminished to between 15% and 22%.

With respect to the percent hemi-axis shortening in the contrast ventriculogram, the sensitivity and specificity of the radial segmental ejection fraction varied as a function of the designated lower limit. A clinically relevant decision, ie, with high specificity, was obtained only on designation of a 2-sigma lower limit, but this was achieved at the cost of a low sensitivity (57%), especially in patients with hypokinesis.

The advantage of the "three-dimensional" regional ejection fraction determination over hemi-axis shortening, the accuracy of which is highly dependent on the number of projections, is that the former method requires only a single projection. This is particularly desirable for imaging with short acquisition times, eg, during exercise testing or monitoring of pharmacologic interventions.

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