Comparison of Scintigraphic Count-Volume and Geometric Methods for Measuring Left Ventricular Ejection Fraction*

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A comparison of geometric and count-volume scintigraphic methods for measuring left ventricular ejection fraction (EF) is presented. The particular count-volume method used is a modification of an established first-pass technique. It is shown that a modification of the technique is necessary to prevent a positive bias in the EF estimate due to Poisson noise. Using the same simulated data, EF estimates by the modified technique were always closer to the actual EF volume than were the estimates by the original method. Maximum Likelihood estimates were also more accurate than were the other two estimates. In 56 patients with either acute myocardial infarcts or unstable angina pectoris, the scintigraphic single-plane gated geometric method tended to overestimate EF in each of the patient groups when compared with the geometry-independent count-volume estimates. The results also point out that the error in the geometric estimates tended to be greater for larger ejection fractions and appears to be due to the systematic underestimation of end-systolic volumes.

1. INTRODUCTION

Left ventricular ejection fraction (EF), an important index of cardiac function, is commonly measured by contrast angiography at cardiac catheterization (Chapman et al., 1958; Dodge et al., 1960; Sandler and Dodge, 1968; Sandler, 1970; Rackley, 1976) and, increasingly more often, by nonhazardous electrocardiographically gated scintigraphic angiocardiography (Mullins et al., 1969; Rigo et al., 1974; Twieg et al., 1977). Ejection fraction is determined by measuring left ventricular end-diastolic and end-systolic volumes (EDV and ESV, respectively), and using the definition

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EF \triangleq \frac{EDV - ESV}{EDV}.
\] (1)

In general, the volumes are determined by comparing a geometric model (e.g., a general ellipsoid, ellipsoid of rotation, multiple cylinders) with angiographic

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ventricular outlines in single or orthogonal views. These models are probably less suitable for the end-systolic ventricle than for the end-diastolic ventricle, since irregularities in the endocardial surface are accentuated at end-systole (Sandler, 1970; Davila and Sanmarco, 1966; Chapman, 1966). It has been noted that these biplane or single-plane geometric methods often overestimate EF (Sandler, 1970), although variations in the technique of outlining end-systolic images may lead to systematic underestimation of EF by some observers (Sandler, 1970; Davila and Sanmarco, 1966). Furthermore, empirical regression formulas used to correct estimates of volume in these methods (Rackley, 1976) may not be appropriate in individual patients with highly asymmetrical ventricles or localized wall motion defects such as those occurring in patients with ischemic heart disease. Despite these difficulties, application of geometric models to single-plane and biplane angiocardiograms remains the accepted “gold standard” of left ventricular volume and EF measurement.

Geometry-independent measurements of EF in patients are possible with scintigraphic techniques which relate ventricular volume to activity within the ventricle. A particularly convenient count-volume method originated by Schelbert et al. (1975) fits a sinusoid to the left ventricular time-activity curve. The amplitude of the sinusoid as estimated from root mean square (rms) deviation of data points is assumed to correspond to the variation in ventricular volume and is compared to the peak level of the activity at each end-diastolic period to compute ejection fractions. However, this method overestimates ejection fractions. Thus, three methods based on the sinusoidal model of left ventricular volume changes are investigated in the present study. The first is the method of Schelbert et al. (1975). The second estimate, which is merely a first-order correction for the contribution of Poisson noise to the first estimate, appears to be more accurate when both estimators are applied to simulated time-activity curves and the resulting ejection fractions are compared. The third method or “maximum likelihood estimator” when applied to the same data is apparently more accurate than the first two methods.

However, each of these count-volume methods is subject to random errors due to improper choice of the ventricular area of interest and improper background correction (Schelbert et al., 1975) and there is no apparent reason to expect a systematic bias in count-volume EF estimates.

In order to investigate the nature of any systematic errors in EF by the geometric method when applied to scintigraphic angiocardiography in patients with acute myocardial infarctions (MI), single plane geometric EF estimates are compared with count-volume EF estimates.

II. COUNT-VOLUME EJECTION FRACTION ESTIMATES

The premise of the count-volume ejection fraction estimates is simple. Given a constant tracer concentration within a cardiac chamber whose volume is decreasing, the fractional decrease in count rate detected from the chamber should be identical to the fractional decrease in volume independent of the shape of the chamber. To estimate ejection fraction, measurements of ventricular activity are then made at several end-diastolic and end-systolic periods.