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# Two-Dimensional Echocardiographic Evaluation of Left Ventricular Ejection Fraction by the Ellipsoid Single-Plane Algorithm: A Reliable Method for Assessing Low or Very Low Ejection Fraction Values?

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**Key Words**
Two-dimensional echocardiography
Area-length method
Radionuclide angiography
Ejection fraction
Regression analysis

**Abstract**
The reliability of two-dimensional (2D) echocardiographic estimation of left ventricular ejection fraction (EF) is commonly recognized, but no satisfactory data are available about the accuracy of low or very low EF values determined by 2D echocardiography (ECHO-EF). The purpose of our study was to assess the reliability of low ECHO-EF values obtained using a simple time-economical algorithm such as the ellipsoid single-plane area-length method. Radionuclide angiography (RAD-EF) was taken as the standard of comparison. We studied 59 consecutive patients (31 women and 28 men) referred to our echocardiographic laboratory. Both 2D echocardiography and radionuclide angiography were blindly performed within 48 h of one another. EF was calculated by the two methods and then compared. Data were globally analyzed. Furthermore, data were divided and analyzed according to the ECHO-EF cut-off point of 50%. An ECHO-EF value of 50% was chosen to conventionally distinguish between low ECHO-EF values and normal-high ones. Data were plotted, and the line of equality and the regression lines were drawn. Regression line slopes, correlation coefficients, means and standard deviations were calculated. The agreement was analyzed by calculating the mean difference (RAD-EF – ECHO-EF) and the standard deviation of the differences. ECHO-EF was linearly related to RAD-EF even when data were split. In particular, as regards ECHO-EF $\leq 50\%$, the regression line practically overlapped the line of equality, and the two methods showed both a strong correlation and a good degree of agreement. Regarding ECHO-EF $>50\%$, the association between the two methods was lower and the slope of the regression line was quite different from the line of equality. In conclusion, echocardiographic estimation of EF using the ellipsoid single-plane area-length method seems to be sufficiently accurate to evaluate low or very low EF values. For normal-high values, this method underestimated EF calculated using radionuclide angiography, and it showed a minor degree of agreement.

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## Introduction

Left ventricular ejection fraction (EF) is one of the most important indices for the assessment and prognosis of acquired heart disease [1–3]. The quantitative application of two-dimensional (2D) echocardiography is a useful noninvasive method of evaluating EF (ECHO-EF) [4–9]. However, all of the echocardiographic algorithms are not easily applicable to routinely practice. We previously pointed out that ECHO-EF, calculated as the average derived from five consecutive beats, by the single-plane area-length method using the four-chamber view has a high degree of accuracy, and it is not influenced by obesity [10].

Nevertheless, another important question is whether ECHO-EF is reliable even when low or very low values are obtained. This can be very important as long as a low EF is a negative prognostic index. The reliability of ECHO-EF estimation is commonly recognized, but no satisfactory data are available particularly in comparison with another technique.

Hence, the purpose of our study was to assess the reliability of low ECHO-EF values obtained using the ellipsoid single-plane area-length method. Radionuclide angiography was taken as the standard of comparison.

## Methods

*Patient Selection and Study Procedures*

We studied 59 consecutive patients (31 women and 28 men) referred to our echocardiographic laboratory. Only the patients with evident regional wall motion abnormalities, established through standard 2D echocardiographic examination, had been excluded from the study. Both 2D echocardiography and radionuclide angiography were performed within 48 h of one another, during which time there was no change in the patient medical status or medical regimen. Each examination was performed blindly, without knowledge of both patient clinical data and the aim of investigation. Informed consent was obtained from all patients.

*Radionuclide Study*

Systolic function was evaluated at rest with the gated blood pool method [11], using a computerized large-field scintillation camera (STARCAM 400, General Electric) with a high-resolution 1.5-inch parallel hole collimator. Radionuclide angiography was performed and EF (RAD-EF) was calculated as previously described [12].

*Echocardiographic Study*

2D echocardiograms were obtained using an ESAOTE BIOMEDICA computer-aided ultrasonoscope equipped with 2.5- and 3.5-MHz phased-array transducers. A standard VHS video format was used for recordings. The 2D echocardiographic study was performed including standard parasternal long-axis and short-axis views, and apical four- and two-chamber ones. On the apical four-chamber view, end-diastolic volume and end-systolic volume were used for the determination ECHO-EF, as previously described [10], using the ellipsoid single-plane algorithm. The end-diastolic and end-systolic frames from five consecutive beats were selected, and the endocardial outlines were traced. Mean EF was automatically calculated by the echocardiographic processing system. In our laboratory, EF calculated on five consecutive beats permitted optimal reproducibility and accuracy.

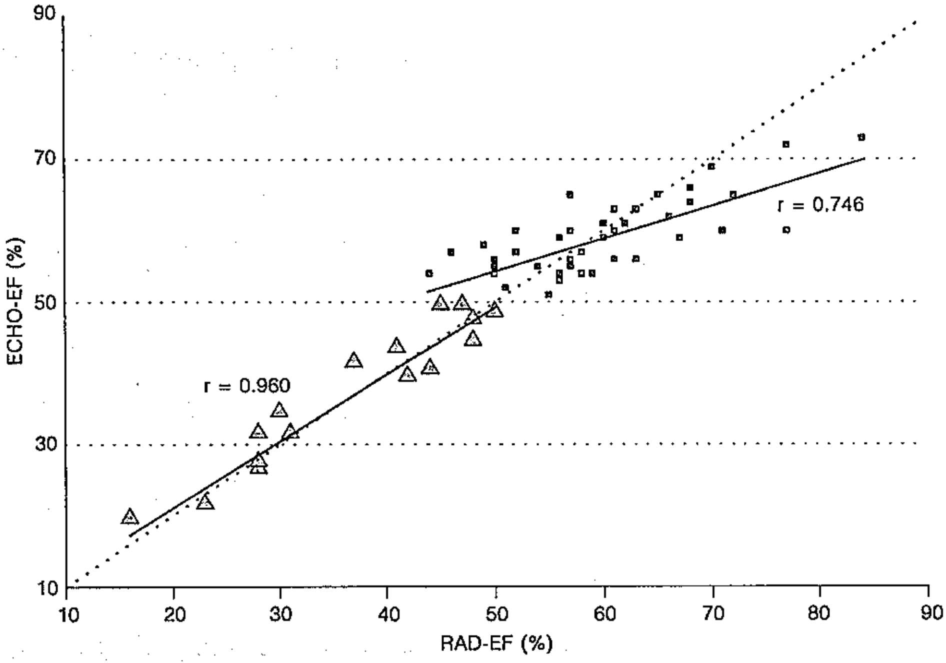
*Data Analysis*

Statistical analysis was conducted with the use of the Statistical Package for the Social Sciences for Windows. Values are reported as means ± SD. A two-tailed paired t test was used to compare means. The correlation coefficients, linear regression analysis and analysis of variance on regression were determined by conventional methods. Moreover, we used the approach proposed by Bland and Altman [13] to assess the degree of agreement between the two methods utilized to calculate EF.

Data were globally analyzed. Furthermore, data were divided and reanalyzed according to the ECHO-EF cut-off point of 50%. An ECHO-EF value of 50% was chosen to conventionally distinguish between low ECHO-EF values and normal-high ones. The first step was to plot the data and draw the line of equality and the regression lines. Regression line slopes and estimated standard errors of the slopes, correlation coefficients, means and standard deviations were calculated. The second step was to analyze the agreement by calculating the mean difference (RAD-EF – ECHO-EF) and the standard deviation of the differences, and then to plot difference against mean for EF data.

## Results

Figures 1 and 2 display relationship and agreement between the two methods, respectively. Descriptive data are summarized in table 1. In each column, we found no statistically significant difference between ECHO-EF and RAD-EF means. ECHO-EF was linearly related to RAD-EF. The close relationship was highly statistically significant ($r = 0.929$; $p < 0.0001$, slope of regression line = 0.790 ± 0.042). However, when the data were divided according to the ECHO-EF cut-off value of 50%, some important differences became apparent. For ECHO-EF ≤50%, the regression line (slope = 0.923 ± 0.072) practically overlapped the line of equality, and the two methods showed both a strong correlation ($r = 0.960$; $p < 0.0001$) and a good degree of agreement. On the contrary, when the ECHO-EF data >50% were analyzed, the association between the two methods was lower ($r = 0.746$; $p < 0.0001$) and the slope of regression line (0.457 ± 0.064) was quite different from that of the line of equality. In this case, 2D echocardiography usually underestimated radionuclide EF. Moreover, there was a minor degree of agreement.

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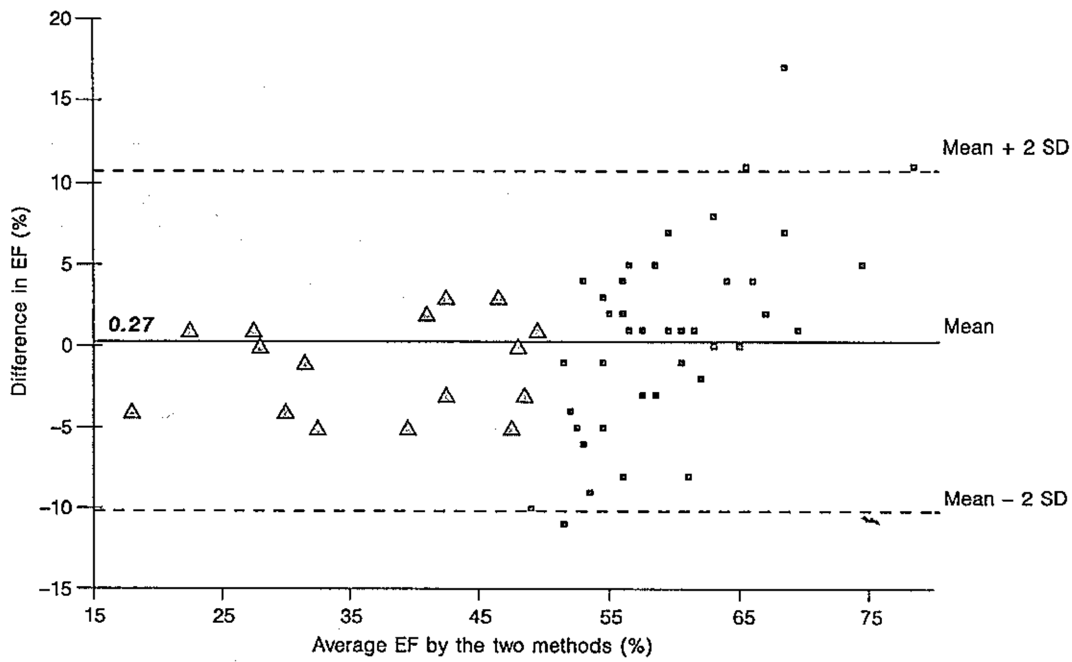


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**Fig. 1.** Relationship between ECHO-EF (area-length method on five consecutive beats) and RAD-EF: the line of equality, each EF estimation, regression lines and correlation coefficients are displayed. △ = Patients with ECHO-EF ≤50%; □ = patients with ECHO-EF >50%; —— = regression line; --- = line of equality.

**Fig. 2.** Difference against mean for EF data. Lines, corresponding to the mean ± 2 SD of all data, are also displayed. △ = Patients with ECHO-EF ≤50%; □ = patients with ECHO-EF >50%; —— = regression line; --- = line of equality.

**Table 1.** Descriptive data (means ± SD)

| | All the patients (n = 59) | Patients with ECHO-EF ≤50 (n = 16) | Patients with ECHO-EF>50 (n = 43) |
|---|---|---|---|
| Age, years | 52.7±13.7 | 54.1±12.3 | 51.6±14.1 |
| Body mass index, kg/m$^2$ | 31.2±7.8 | 33.3±7.9 | 30.6±7.7 |
| Difference in EF, % | 0.27±5.25 | −1.19±2.93 | 0.81±5.82 |
| ECHO-EF, % | 53.5±11.8 | 37.8±10 | 59.4±5.3 |
| RAD-EF, % | 53.8±13.9 | 36.6±10.4 | 60.2±8.57 |

## Discussion

The EF is one of the most widely used measurements of left ventricular systolic function and represents an important prognostic factor in the natural history of cardiac disease and the assessment of the operative risk. 2D echocardiography is a well-established technique for estimating left ventricular EF, and the single-plane area-length method is a simple time-economical algorithm that has proved to be a good method for this purpose [14, 15]. Moreover, we previously pointed out that its evaluation by the area-length method is not influenced by obesity and has a good reproducibility. On the other hand, this investigation aimed at answering another important question. Is 2D echocardiography a reliable method for assessing EF when the obtained value is below or equal to 50%? We found that there was a high degree of agreement between ECHO-EF and RAD-EF just when low ECHO-EF values were analyzed. In fact, the regression line for echocardiographic values below or equal to 50% almost overlapped the line of equality with a high degree of correlation and a good degree of agreement. On the contrary, ECHO-EF values above 50% underestimated the EF calculated using the standard technique. In this case, the regression line slope was quite different from that of the equality line (0.457 vs. 1) and there was a minor degree of agreement particularly for the highest values. We do not know why this difference exists, and it was not the aim of this investigation, but it may be very important to know whether low ECHO-EF values are reliable. Our study points out that low ECHO-EF values are more reliable than normal high ones. We think that such an evidence can be of great interest in clinical practice. Moreover, it confirms the high value of 2D echocardiography in giving precious information on left ventricular function especially when it is impaired. However, we think that the fact we used the area-length algorithm on five consecutive beats has to be underscored.

In conclusion, ECHO-EF using the ellipsoid single-plane area-length method seems to be sufficiently accurate to evaluate low or very low EF values. As regards normal-high ECHO-EF values, this method shows a minor degree of agreement in comparison with RAD-EF.

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