

# Reproducibility of Echocardiographic Left Ventricular Function Assessment by an Automated Technique

G Longobardi, DF Vitale, G Furgi, G Santopietro, Q Bosco, A Nicolino, C Picone, F Rengo

Fondazione S. Maugeri IRCCS, Telesse Terme, Italy

## Abstract

*Reliable automatic border detection algorithms are the critical point for an effective routine application of ultrasound left ventricular function (LVF) assessment.*

*Aim of this study was to assess the reproducibility of the LVF parameters obtained using an automated commercially available system (HP SONOS 5500B).*

*The residual error of the regression analysis of two repeated measures of each parameter was computed and compared with the mean differences observed between patients with and without myocardial infarction or clinical evidence of heart failure.*

*The reproducibility ranges from good to inadequate depending on the considered parameter and on the affecting disease form. In particular, indexes of systolic performance have a better reproducibility than diastolic one.*

## 1. Introduction

The clinical relevance of left ventricular function assessment by means of echocardiography is well recognized and gives account for the widespread diffusion of this procedure.

However, objective and easy to perform procedure requires the implementation of reliable automatic algorithms for endocardial border detection.

The critical relevance of this step has been well recognized as revealed by the great amount of effort that has been spent in the past years developing an algorithm able to accurately quantify left ventricular function by echocardiography. (1-5).

However, so far, several limitation have restricted the widespread use of these techniques in the clinical settings. The major of these limitations being related to the required extensive and time consuming off-line computations.

Aim of the present work was to assess the reproducibility of LVF parameters computed in real time on a beat to beat basis with an automatic border detection algorithm based on acoustic quantification (6).

## 2. Method

Between January and March 2001, after written informed consent was obtained, 143 unselected in-hospital patients scheduled for two-dimensional echocardiography were enrolled in the study. Patients were affected by coronary artery disease, valvular disease or cardiomyopathy.

Patients with atrial fibrillation were excluded from the study.

Images were obtained with the patients in the left lateral decubitus position, using a Hewlett Packard Sonos 5500 model M2425A, equipped with an S4 transducer.

Acoustic quantification (AQ) was performed as described by Perez et al. (6), being careful to obtain images with good visual tracking of endocardial borders.

Images from apical 4-chamber window were obtained and values for end diastolic volume (EDV), end systolic volume (ESV), ejection fraction (EF), peak of ejection rate (PER), peak of rapid filling rate (PRFR) and atrial filling fraction (AFF) were averaged over 5 cardiac cycles. Images were excluded from analysis if less than 75% of the endocardial border was visualized.

In 97 (68%) patients out of 143 the study quality was considered adequate and the examination was repeated by another operator after  $2.9 \pm 2.3$  days.

Linear regression analysis between the pairs of values of each parameter was performed and the residual error around the regression line (RE) was used as measure of the reproducibility.

LVF parameters were assessed in 103 patients affected by coronary artery disease, 45 of them had evidence of an old myocardial infarction (MI) while 12 had dilated cardiomyopathy (DCM).

Absolute difference between coronary artery disease patients with and without myocardial infarction or dilated cardiomyopathy compared to the RE are used to assess the relevance of the difference itself.

## 3. Results

The mean $\pm$ SD of the LVF parameters of each subgroup of the CAD patients are reported in table 1.

Table 1. Mean±SD of the LVF parameters in patients with coronary artery disease (CAD), coronary artery disease and previous myocardial infarction (MI) and dilated cardiomyopathy. (sv=stroke volume. For others abbreviation see text).

Param.	CAD	IM	DCM
EDV (ml.)	114±34	125±36	212±57
ESV (ml.)	56±22	69±22	156±57
EF (%)	51±7	46±7	28±8
PER (edv/s)	3.2±0.8	3.1±0.7	1.5±0.3
PRFR (edv/s)	3.3±0.9	2.8±0.8	1.8±0.5
AFF (%)	28±13	31±13	27±14
PRFR (sv/s)	6.5±1.8	6.1±1.8	6.9±3.6

RE values and the absolute differences between coronary artery disease patients with and without myocardial infarction or dilated cardiomyopathy are reported in table 2.

Table 2. RE and absolute differences between CAD subgroups.

Param.	RE	CAD-IM	CAD-DCM
EDV (ml.)	24.5	11	98
ESV (ml.)	14.2	13	100
EF (%)	3.5	5	33
PER (edv/s)	0.6	0.1	1.7
PRFR (edv/s)	0.9	0.5	1.5
AFF (%)	9.1	3	1
PRFR (sv/s)	1.6	0.4	0.4

In order to show the different reproducibility behavior between systolic and diastolic indexes the scatter plot of the EF and the PRFR (edv/s) are plotted in figure 1 and 2.

#### 4. Discussion and conclusion

Reproducibility assessment of LVF parameters should be performed in each echocardiographic laboratory in order to assure the consistency with the report of other laboratories.

Our results are in agreement with data reported by others (7) and evidence a marked difference in the reproducibility quality between the single indexes considered.

In fact, volume measurements (EDV and ESV) and the derived EF show a better reproducibility than the remaining parameters. This can be obtained by

comparing the RE value with the absolute differences between CAD subgroups. Greater the value of the intergroup difference compared to the corresponding RE, greater the chances that the observed difference is related to factors inherent to the group more than to the variability of the parameter itself and *viceversa*.

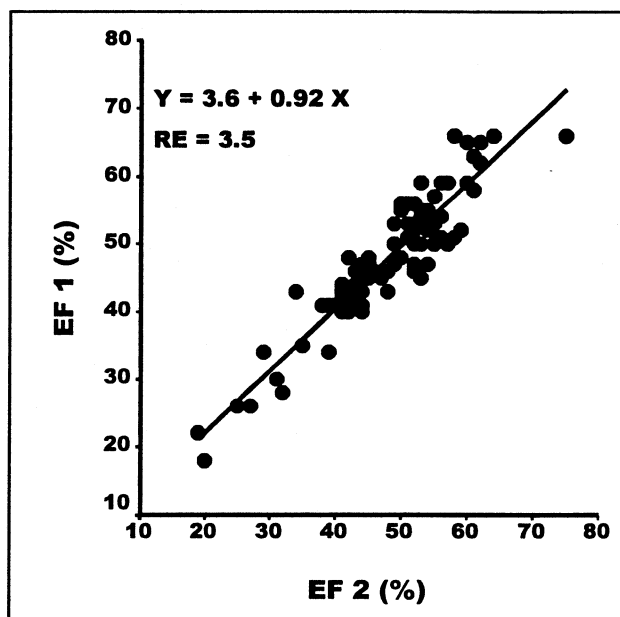


Figure 1. Scatterplot of the EF.

The same inference can be derived visually comparing the dispersion around the regression lines of figure 1 and 2.

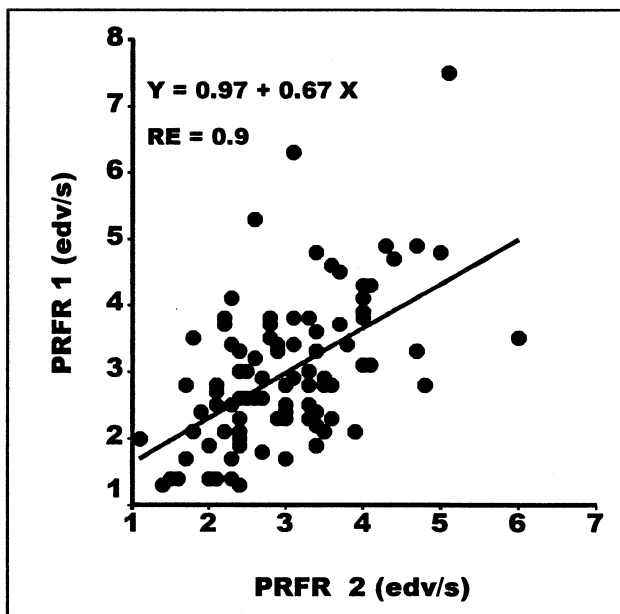


Figure 2. Scatterplot of the PRFR.

The derivative nature of PER and PRFR gives account of these results given the greater sensitivity to errors in the derivative calculations, while in the case of the AFF the greater variability of the end-diastolic portion of the left ventricular volume curve may be involved.

In summary, when left ventricular function indexes are divided in "systolic" and "diastolic" the first show a better reproducibility behavior than the second.

Data reported in table 1 lead to another observation, not directly related to the reproducibility, but that is worth to be mentioned.

Peak of rapid filling rate is normalized to end-diastolic volume or to stroke volume. The meaning of this diastolic parameter as a consequence become dependent upon the particular normalization parameter. In addition, normalization of PRFR by end-diastolic volume creates a "diastolic" index that is heavily influenced by ejection fraction. This aspect is evident in table 1 where PRFR normalized by end-diastolic volume shows a marked reduction in the patients with dilated cardiomyopathy. The erroneous conclusion that these patients evidence diastolic abnormalities can be avoided observing that the PRFR normalized by stroke volume, taking into account the concomitant reduction of the EF, show similar values in all groups.

In practice, it is helpful in interpreting results to use more than a single normalization parameter for PRFR (8).

## References

- [1] Jenkis RE, Garrison JB. Automatic contouring for two-dimensional echocardiography. Johns Hopkins APL Technical Digest 1980;1139-43.
- [2] Garcia E, Gueret P, Bennet M, Corday E, Zwehl W, Meerbaum S, Corday S, Swan HJ, Berman D. Real time computerization of two-dimensional echocardiography. Am Heart J 1981;101:783-92.
- [3] Collins SM, Skorton DJ, Geiser EA, Nichols JA, Conetta DA, Pandian NG, Kerber RE. Computer-assisted edge detection in two-dimensional echocardiography: comparison of anatomic data. Am J Cardiol 1984;53:1380-7
- [4] Conetta DA, Geiser EA, Oliver LH, Miller AB, Conti CR. Reproducibility of left ventricular area and volume measurements using a computer endocardial edge detection algorithm in normal subjects. Am J Cardiol 1985;56:947-52.
- [5] Geiser EA, Wilson DC, Gibby GL. Applications of cross correlation techniques to the quantitation of wall motion in short axis two-dimensional echocardiographic images. J Am Soc Echo 1990;3:266-75.
- [6] Tsujita-Kuroda Y, Zhang G, Sumita Y, Hirooka K, Hanatani A, Nakatani S, Yasumura Y, Miyatake K, Yamagishi M. Validity and reproducibility of echocardiographic measurement of left ventricular ejection fraction by acoustic quantification with tissue harmonic imaging technique. J Am Soc Echocardiogr 2000;13:300-5.
- [7] Perez JE, Waggoner AD, Barzilai B, Melton HE, Miller JG, Sobel BE. On-line assessment of ventricular function by automatic boundary detection and ultrasonic backscatter imaging. J Am Coll Cardiol 1992;19:313-20.
- [8] Bonow RO. Radionuclide angiographic evaluation of left ventricular diastolic function. Circulation 1991;84 (suppl 1): I-208-I-215.

Address for correspondence.

Giancarlo Longobardi, MD.  
Fondazione Salvatore Maugeri, IRCCS  
Via Bagni Vecchi  
82037 Telese T. (BN)  
Italy.  
E-mail address : glongobardi@fsm.it