Correlation and Concordance between Echocardiographic Measurements obtained during Echocardiography and Digitized Image Measurements – Transversal Study

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Objective

To evaluate the correlation and concordance between the measurements of echocardiographic analysis of cardiac dimensions obtained through the Echo off-line applicative (software for obtaining digitized image measurements in a dedicated workstation) available to public domain, and those obtained through the conventional method.

Method

Transversal contemporary study, of 56 randomized patients whose images were obtained during examinations. The measurements of the M mode and 2D, were done in the ventricles, left atrium, and aorta by the Echo off-line program. These measurements were compared to those obtained by another professional, through Pearson's correlation test (r) (alpha = 0.05) and by concordance analysis (Bland and Altman).

Result

The measurements carried out by the Echo off-line system showed (r) that varied from 0.85 to 0.98. The analysis of concordance showed that for most measurements, the mean difference between the methods was approximately zero. The variation of absolute values did not show, in average, a clinical significance. The Echo off-line applicative allows a reduction of approximately 30% in the time spent to obtain the measurements.

Conclusion

This study demonstrated the accuracy of the Echo off-line program to measure cardiac dimensions in a dedicated workstation, showing that it can be routinely used in echocardiography labs.

Key words

Interpretation of image guided by computer, echocardiography, public domain program.

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Ever since the initial echocardiography studies by Edler and Hertz in 1953, much has been researched, regarding technology for the optimization of this diagnostic method.

The protocol of the echocardiographic examination, in addition to the diagnosis itself, includes performing a set of cardiac structure measurements that have been well validated in literature[1], which are used as parameters for the evaluation of cardiac performance and follow up of cardiopathy evolution.

The values of the systolic and diastolic volumes of the left ventricle, ejection fraction and ventricular mass have been well validated by studies that demonstrated a good correlation with the findings of angiocardiographic measurements[2,3]. The normal values of cavity dimensions for atriums and ventricles have been previously established[4,5] for the bidimensional and the M-mode echocardiography [6,7].

Feigenbaum[8], in 1988, was the first to describe the use of image acquisition, in a digital format, in cardiovascular diseases. The use of digital echocardiography allows the attainment of high-quality images that can revised, enabling the analysis of echocardiographic data in a dedicated workstation, allowing the immediate comparison with previous examinations[9].

A dedicated workstation consists in a computer with a board able to capture images and a program that allows the calibration and mensuration of the images obtained during the conventional examination and stored as digital images.

The digitalization of images can reduce the time needed to perform examinations and consequently, their cost, also allowing the direct sending of images to reference centers eliminating the need for patient transportation.

Regarding these advantages, it is mandatory to establish the precision of the measurements performed in a dedicated workstation in order to allow their use in clinical practice. Therefore, the primary objective of this study is to evaluate the correlation and the concordance between the echocardiographic measurements through the M-mode and bidimensional ones, obtained through the use of the software for digital image capture at the dedicated workstation developed in our institution, with those obtained conventionally during the routine examination of patients, thus demonstrating the applicability of this program.

Methods

A transversal, contemporary study was carried out with 56 patients, referred to the Service of Graphic Methods for echocardiographic examination, from August to November 2002, by clinical indication of their assistant physician, regardless of the presence of a cardiac pathologic condition and type of cardiologic disease. These patients were randomly selected through a program that was especially developed for such task (freely available at www.cardiologia.org.br).

Each patient selected for the study received an informed written consent form approved by the Ethics Committee of the Institution where the study was carried out, in which the patients agreed to allow the capture and use of their images for research purposes.

Six patients were excluded from the sample, according to the following exclusion criteria: 1) limited left longitudinal parasternal echocardiographic window; 2) presence of segmental alterations of the septum and posterior walls; and 3) refusal to sign the written informed consent.

Echocardiographic measurement mensuration system – A system was developed with two modes of data acquisition and storage: one, which is the access to the local database, allowing the integration with the hospital medical report system, automating the process of data recording of the examinations performed; and the other, the access to files, in which the image is directly read from a JPEG-type file (with BMP as an option) and the results are recorded in a text file. This mode allows the utilization of the Echo off-line applicative at any situation, eliminating the need to access the institution database (the program is freely available at: www.cardiologia.org.br).

The LAUDOS software was developed in Delphi 5.0, initially utilizing the database in MDB (Microsoft Database) format. Posteriorly, the applicative was rewritten using the SQL pattern aiming at its integration with the institution Oracle database.

The interpretation module at the workstation (off-line) uses a graphic interface, in which the scale parameters are adjusted. The measurements are performed on static images in JPEG or BMP format, acquired through hardware and software by ATI Technologies, coupled to a PC with Microsoft Windows® as the operational system. The applicative, in addition to the graphic interface, allows the user to define groups of measurements, medical file phrases and models that facilitate the descriptive process and permits the data crossing for scientific research.

To implement the Echo off-line, the C++ Builder tool, version 5.0, from Inprise, was used. C++ *Builder* is a RAD-type (Rapid Application Development) tool that uses C++ language in the code implementation. The interface with the user was constructed with the use of components denominated Form (formularies).

The echocardiographic examinations were carried out with an echocardiography machine (Sonos 2500, Hewlett Packard, Andover, Mass., USA), with a multifrequency transducer from 2 to 2.5 MHz, coupled to an ATI all-in-wonder video capture board, installed in a Pentium II PC, connected to the Institution corporative net.

The measurement program in an Echo off-line dedicated workstation was installed in only one computer at the institution, with the following configuration: Pentium 4 with 256 Mb of memory, running on a Windows 2000 platform, LG Studioworks 995E 17”

monitor, with brightness control at 66 and contrast at 68, Hauppage win/TV 878 video board and Logitech mouse model DGPGF.

The echocardiographic images were captured at parasternal longitudinal sections in M-mode and bidimensional echocardiography, at the aorta and left atrium levels and at the systolic and diastolic ventricle levels, according to the recommendations of the American Society of Echocardiography Committee on Standards[2], by only one echocardiographist. Each image employed in the measurement of variables was digitized, using a 640 x 480 pixel resolution and stored as a JPEG file. After data collection, the patient's examination proceeded as a routine one.

A second echocardiographist performed the same measurements in M-mode and bidimensional echocardiography, using the Echo off-line program. Each image was measured twice, with a minimal interval of one day between the measurements, with the objective of obtaining the intra-observer correlation and the interobserver correlation and concordance analyses, in order to verify the tool reproducibility.

For each M-mode and bidimensional echocardiography section, the Echo off-line program was calibrated in order to allow high-accuracy measurements, using the scale provided by the program. The time for obtaining these measurements was also recorded through the applicative.

The measurements were recorded in a medical examination record, which also included the patient's admittance and release times. The whole procedure was recorded in VHS videotape.

The echo off-line presentation screen is shown in Figure 1. The largest part of the screen shows the echocardiographic image. The objective was to attain a simple and clear visual organization. The buttons were placed in an order that follows the natural use of the tool. It initiates by opening the image to be measured, followed by the scale calibration and then the measurements are performed (Fig. 1).

The measurements in M-mode and bidimensional echocardiography are presented as means and standard deviations.

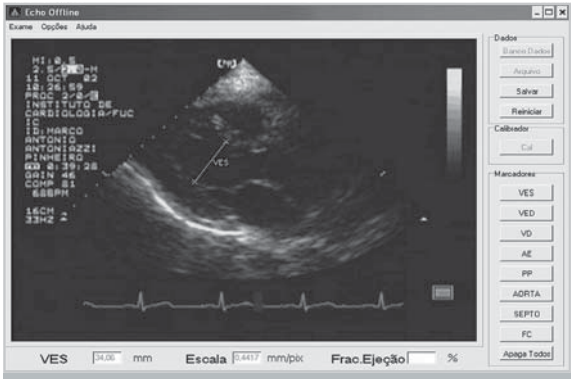

***Fig. 1** - Echo off-line program presentation screen*

Pearson's correlation coefficients were calculated between the measurements obtained through the conventional examination and those obtained through the program to attain digitized image measurements in a dedicated workstation, considering a critical alpha = 0.05. This coefficient indicates how much two variables are linearly correlated; however, it does not correctly expresses the concordance between the measurements.

The two methods were additionally compared by Bland-Altman concordance analysis, which permits to establish concordance limits between clinical measurements carried out by two different methods[11].

The intra-observer variation analysis for the measurements obtained with the aforementioned program was performed using Bland-Altman concordance analysis[11].

Results

Of the fifty-six patients studied, 32 (57%) were females and 24 (43%) were males. Mean age was 48 years, ranging from 14 to 86 yrs. The images were captured during echocardiographic examinations, from August to November 2002.

Table 1 shows the means and respective correlation coefficients between the measurements obtained conventionally and with the Echo off-line program in M-mode; Table 2 shows the means the respective correlation

Table 1 – Means and correlation coefficients between the measurements carried out conventionally and with the Echo off-line program in M-mode

Dimensions	Conventional Mean ± sd	Echo off-line Mean ± sd	R Pearson	p
AO	31.54 ± 3.48	31.07 ± 3.44	0.88	0.0000001
LA	37.78 ± 9.03	37.03 ± 8.51	0.97	0.0000001
RV	20.74 ± 4.13	21.07 ± 3.83	0.90	0.0000001
LVD	50.48 ± 7.00	48.89 ± 6.80	0.96	0.0000001
LVS	31.64 ± 8.21	30.66 ± 8.14	0.97	0.0000001
Septum	8.81 ± 1.70	9.01 ± 1.69	0.90	0.0000001
PW	8.64 ± 1.76	8.88 ± 1.82	0.91	0.0000001

AO: aorta; LA: left atrium; RV: right ventricle; LVD: left ventricle diastole; LVS: left ventricle systole; PW: posterior wall

coefficients between the measurements obtained conventionally and with the Echo off-line program in bidimensional mode.

These two tables show that there are adequate correlation rates between the measurements performed by the two methods, which varied from 0.85 to 0.98. We also observed that the measurements obtained through the bidimensional mode showed higher correlation rates when compared to those obtained through the M-mode, with an intra- and inter-observer variation of about 10%.

The measurements with the highest variations between the methods in our study were those of the aorta, the right ventricle and the parietal thickness at the M-mode, which have been previously described in literature as the ones presenting the highest inter-observer variation[21]. The right ventricle dimension presents the highest variation among all measurements, as it depends on the patient's position.

The graph shows the analysis of concordance performed for the left ventricle, in systole and diastole, between the two methods of measurement of the echocardiographic cavitary dimensions in M-mode and bidimensional mode (Fig. 2).

The analysis of concordance between the measurements obtained through the M-mode and bidimensional mode showed to be adequate for most of the measurements, as the mean difference between the methods was very close to zero.

The analysis of variance of the intra-observer measurements in M-mode and bidimensional mode was carried out using Pearson's correlation, in order to evaluate the reproducibility of the measurements performed by the same observer, who carried them out with the Echo offline applicative. The correlation indexes varied from 0.81 to 0.98, demonstrating that the use of the applicative is adequate, as shown by the reproducibility of the measurements.

The comparison between the times used in both methods indicates that, when using the Echo offline applicative, there is a decrease of at least 30% in the time used to perform the measurements, when compared to that spent to perform them with the echocardiographer (conventional method).

The analysis of the echocardiographic measurements at the Echo offline program allowed a mean reduction of 1,000 min/month in time of machine use, allowing an increase of approximately 50 examinations a month, performed through the echocardiographer.

Discussion

The routine of echocardiographic examinations includes, in addition to a detailed physical assessment of the patient, obtaining images and measurement of quantitative variables. The wish to perform such measurements outside the examining room was, for several years, hindered by the fact that the workstations dedicated to such functions were not cost-effective; the technological development of informatics allowed a more accessible operational cost.

The advantage of using digital echocardiography is obtaining high-quality images that can be reviewed, allowing the analysis of echocardiographic data off-line, with the calculation of dimension and Doppler measurements, without the need for large spaces, which can be smaller and more organized for storing images. The quantification is simplified with the DICOM *(Digital Imaging and Communications in Medicine*), calibration information, allowing direct measurements to be performed, as well as the generation of electronic reports and database.

The recording in VHS videotapes is universally employed for image storage, as the cost for storing the data in a compression system of JPEG type is around US$1.90 dollars per patient, whereas the cost to store a VHS videotape is around US$0.32 dollars per patient. Thus, the cost of digital image storage is around 6 times higher[13]. However, this cost is justifiable, as the acquisition of computerized systems expedites the delivery of results, besides the fact that results become available at the local net (Intranet) as well as the external net (Internet), allowing a direct correlation

Table 2 - Means and correlation coefficients between the measurements carried out conventionally and with the Echo off-line program, bidimensionally

Dimensions	Conventional Mean ± sd	Echo off-line Mean ± sd	R Pearson	p
AO	29.78 ± 3.38	29.83 ± 3.58	0.90	0.000000
LA	34.51 ± 9.51	34.13 ± 8.48	0.98	0.000000
RV	22.57 ± 3.01	22.76 ± 2.88	0.85	0.000000
LVD	49.06 ± 6.99	48.41 ± 6.92	0.95	0.000000
LVS	32.18 ± 8.43	32.11 ± 8.36	0.98	0.000000
Septum	8.40 ± 1.81	8.96 ± 1.84	0.91	0.000000
PW	8.56 ± 1.98	8.81 ± 1.91	0.89	0.000000

AO: aorta; LA: left atrium; RV: right ventricle; LVD: left ventricle diastole; LVS: left ventricle systole; PW: posterior wall

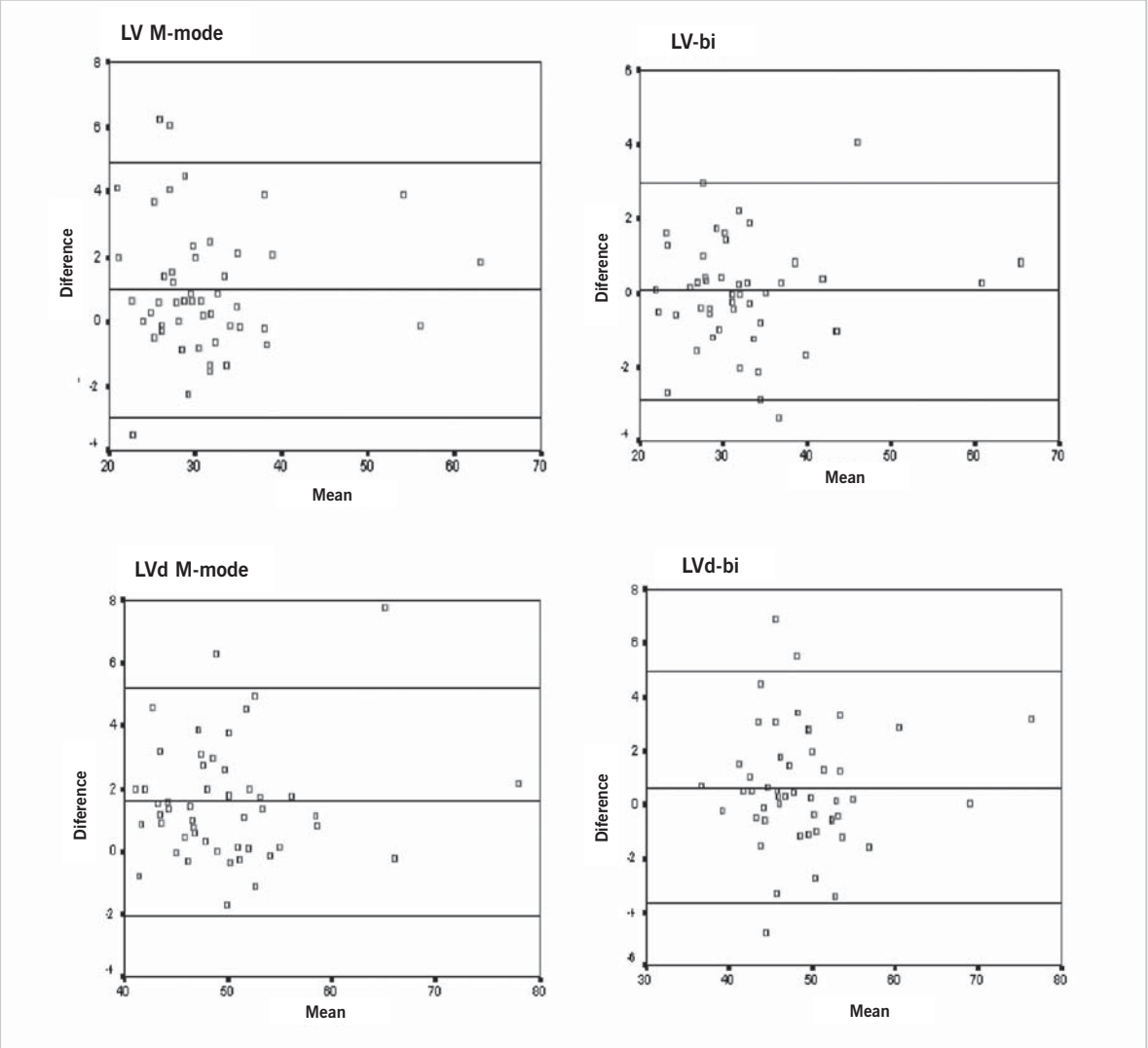

Fig. 2 *- Concordance analysis of the left ventricle measurements*

between the medical file (computerized medical record) and the examination data, reducing the time needed for performing the examinations.

Another advantage of storing images in digital format is the lower probability of image degradation, along with easier data exchange and transmission, allowing a faster and simultaneous comparison with previous examinations[13].

The possibility of sending medical images to reference centers allows patients who are seen at primary and secondary centers to receive a better quality medical assistance, without the need to transport them to tertiary hospitals, as well as favoring the distance education of the physicians caring for such patients, improving the quality of care given by the team working in such centers.

Mohler et al[15] compared interpretations of digital echocardiograms and videotapes in patients with thoracic pain from an emergency department. The concordance rate of the two methods for the analysis of segmental contractility was 94%.

Karson et al[16] demonstrated that digital image storage allows a higher quality of images when compared to videotapes, with compression up to 20:1. This study assessed 179 patients, although only a few images were evaluated.

Soble et al[17] compared analyses of MPEG-1 images with videotape images in a series of 58 patients, and found a concordance of 83%.

The study of Segar et al[18] evaluated 110 examinations recorded simultaneously in videotape and digital format, with a concordance rate of around 83%.

The study of Mobarek et al[19] suggests that the accuracy is not affected at the interpretation of digitized systems, despite the need to perform a significant "clinical compression", i.e., the operator has to limit the recordings to segments or loops of 1 or 2 cardiac cycles. In 93 consecutive patients, the digital data that underwent this type of compression were compared to a

complete study recorded in videotape. The concordance in the interpretation between these two techniques was estimated at being 99%, with a significant reduction of interpretation time.

Haluska et al [20] evaluated the use of digitized images in the diagnosis of patients with valvular diseases. One hundred and one patients with valvular deficiencies were selected and their test results were digitized using the JPEG format, with a 20:1 compression, as well as recorded in VHS. The measured parameters were highly concordant between the two methods.

This study demonstrated that the measurement tool in a dedicated workstation developed at our Institution presents correlation rates that are similar to those reported in other studies, previously described in literature, as well as good reproducibility rates of the intra-observer measurements.

The evaluated system allows a better use of the high-cost equipment, i.e., the echocardiographs, transferring the tasks of measurement and medical reporting to the dedicated work unit, with no ill effects on the diagnosis accuracy. This results in the examination cost decrease, allowing more people to benefit from them.

Due to the results obtained, the tool was incorporated into the medical report system used at the Medical Care Service of our Institution. The applicative prototype used in this study is freely available at the site www.cardiologia.org.br. The program, incorporated to the medical report system, allows the evaluation of the diastolic function and orovalvular lesions, and further studies are necessary in order to test the applicative accuracy for this purpose.

In conclusion, this study demonstrated the accurate and practical use of the Echo off-line program to determine echocardiographic measurements of cardiac dimensions in a dedicated workstation, showing that this program can be routinely used in echocardiography labs.

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