Management of a Patient With Atrial Fibrillation and Heart Failure: Success Using a Multisite Bifocal Pacemaker in the Right Ventricle

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Summary

The purpose of this paper is to discuss the disease progression, assessment, and treatment of a 58-year-old female patient with atrial fibrillation, heart failure, and resistance to drug therapy, who responded to treatment instituted by ablation of the atrioventricular node and implantation of a bifocal pacemaker in the right ventricle. The patient was first seen in 1984 for treatment of hypertension and dilated cardiomyopathy. During the progression of the disease, the patient presented with left bundle-branch block and atrial fibrillation, up until the end of 1999. Despite receiving appropriate medication for treatment of NYHA class IV heart failure, the hospitalizations were becoming increasingly more frequent. In January 2000, a bifocal pacemaker was implanted in the right ventricle following atrioventricular node ablation. Since then, the patient's condition has improved, requiring little medication and few hospitalizations.

Key Words

Heart failure, bifocal pacemaker, atrial fibrillation, atrioventricular node ablation

Introduction

Heart failure is a complex syndrome characterized by the inability of a diseased heart to meet the body's metabolic and tissue needs, or by its ability to only meet these needs at high filling pressures. Heart failure is a progressive disease caused by multiple cardiopathies; its prevalence worldwide has increased in the last few years due to a greater life expectancy in the general population and to improved treatment during the acute phase of a myocardial infarction. Therefore, more people survive the development of heart failure [1]. From the time of its diagnosis, the severity of this complex syndrome increases continuously; patients are frequently hospitalized due to the heart's hemodynamic decompensation. The disease results in high morbidity and mortality rates, with survival rates of 25% in men and 38% in women (during a 5-year period) [2]. Since heart failure is a potentially deadly syndrome, it is important to stratify the risk of death through early identification of those patients with the greatest possibility for occurrence. Therefore, identifying the prognostic factors of heart failure will help in determining more aggressive and optimal therapies, including extreme interventions such as the implantation of a pacemaker or defibrillator and/or heart transplant. The objective of these interventions is the reduction of morbidity and mortality of this complex syndrome [3]. In 1995, a study was conducted using radioactive labeled red blood cells for the quantitative assessment of left ventricle performance [4]. The methodology developed from this study has been accepted by the American Society of Nuclear Cardiology, primarily because the results are not influenced by geometrical alterations of the left ventricle. This radioisotopic ventriculography is a non-invasive, easy-to-use, and low cost assessment method. Recently, this methodology has played an important role in assessing the more progressive treatments for ventricular insufficiency. By digitalizing the information obtained using this method, it is possible to either analyze the left ventricle as a whole, or to separate it into regions in order to study the regional dynamics during the cardiac cycle.

We used radioisotopic ventriculography in comparison to Doppler echocardiography to analyze the hemodynamic parameters of a patient implanted with a bifocal, dual-chamber pacemaker.

Materials and Methods

Case Report

Since January 1984, a 58-year-old female patient has been under our care at the Instituto de Moléstias Cardiovasculares (IMC) in São José do Rio Preto, Brazil, for treatment of hypertension initially controlled with beta-blockers; her Machado Guerreiro test (to detect Chagas disease) was negative. The ECG showed sinus rhythm and an overload in the left ventricle. Follow-up examinations were conducted annually, and the patient's condition was stable using the prescribed medication. In December 1988, the ECG showed left bundle-branch block and left anterior fascicular block. During the July 1994 assessment, the patient presented with atrial fibrillation (AF), although she had few symptoms. In August 1994, she was hospitalized for the AF and was treated with digitalis, amiodarone, diuretics, and an ACE-inhibitor. The ECG showed an ejection fraction (EF) of 41% with severe, diffuse hypokinesia in the left ventricle. The patient was again hospitalized in March 1997 with NYHA class III; from that time on, the hospitalizations became increasingly more frequent, despite increased medication. In June 1999, carvedilol was added to the list of medications, but it was not well tolerated by the patient. Despite this optimal pharmacologic therapy, the patient's condition worsened. In October 1999, the patient was hospitalized again; her condition had deteriorated to NYHA class IV, and she poorly tolerated digitalis and other drugs designed to maintain ventricular stability, even when they were administered intravenously. In January 2000, we performed atrioventricular node ablation and implanted a bifocal, dual-chamber pacemaker (Actros DR with YP 60 BP endocardial leads; all from Biotronik, Germany) in the right ventricle. Figure 1 and Table 1 provide pre-operative data.

Doppler Echocardiography

We used conventional and two-dimensional Doppler echocardiography to assess the patient's condition during right apical and bifocal stimulation. The technique described by Teichholz et al. [5] was used to obtain the EF of the left ventricle (LV) through the M-mode. In this technique, the end-diastolic and end-systolic diameters (EDD, ESD, respectively) were measured, and the LV volume (EDV, ESV, respectively) were calculated by using the formulas:

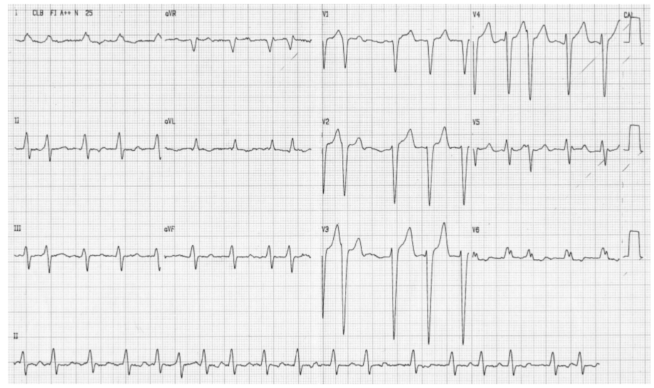

Figure 1. ECG before pacemaker implantation (January 5, 2000). Width of the QRS complex = 180 ms.

- EDV = $(7.0 \times EDD^3) / (2.4 + EDD)$, EDV in cm and EDV in cm^3;
- ESV = $(7.0 \times ESD^3) / (2.4 + ESD)$, ESD in cm and ESV in cm^3

The EF was then calculated from the systolic and diastolic volumes by using the formula:

- EF = $(EDV - ESV) / EDV \times 100\%$

The rhythm of movement of the LV posterior wall also reflects a measure of the systolic function [6], and is the result of the ratio between the amplitude of the endocardial systolic movement and the systolic duration. Another way to assess the LV systolic function through echocardiography is by using the cardiac output (CO), which is obtained by combining data from

Lead position	Threshold (V)	R-wave amplitude (mV)	Impedance (Ω)
Apex	0.5	10.6	1260
Outflow tract	0.5	8.8	600

Table 1. Data obtained at implantation (January 25, 2000). DVI mode, pulse width = 2.5 ms, pulse amplitude = 3.5 V, sensing = 2.5 mV, AV-delay = 200 ms, VV-delay = 15 ms.

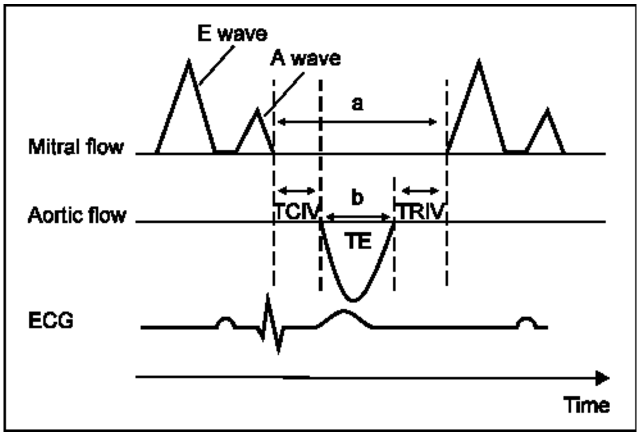

Figure 2. Schematic illustration of the method for obtaining the cardiac performance rate (Doppler-index). The mitral flow tracing is obtained with pulsed-wave Doppler in the upper part of the mitral valve, and the time interval between the A wave of the previous tracing and the E wave of the subsequent tracing is measured (a). Following that, the ejection time (TE) is measured, from the spectral curve of the aortic flow obtained in the LV outflow tract (b). The difference (a - b) results in the sum of the isovolumetric contraction and relaxation periods (TCIV and TRIV, respectively). Doppler index = (a - b) / b.

the two-dimensional scanning and Doppler echocardiography. The systolic volume was calculated by multiplying the area of the LV outflow tract and the integral of the spectral tracing of pulsed-wave Doppler in this region. The CO was the result of the multiplication of systolic volume by the heart rate [7]. A method proposed by Tei et al. [8], which incorporates data from both systolic and diastolic functions, was also used to check the potential benefit produced by resynchronization. This method is based on the ratio between the sum of the periods of isovolumetric contraction and relaxation, which reflects disturbance of the systolic and diastolic phases, and the LV outflow, which represents a parameter of the systolic function (Figure 2). Therefore, a high ratio represents a reduced LV performance.

The effect of resynchronization on the degree of mitral insufficiency was also evaluated by means of measuring the mitral insufficiency jet area in relation to the total area of the left atrium. According to Helmcke et al. [9], small jet areas (< 20%) indicate small regurgitation, and jet areas > 40% denote major mitral insufficiency. In addition, the duration of the regurgitating jet was evaluated, which is directly proportional to the severity of the mitral insufficiency. Recently, tissue Doppler has been used to assess systolic and diastolic functions in a number of pathologies. Since it uses modified filters from the conventional Doppler, the tissue Doppler selectively detects the Doppler variation in the tissues, and is therefore able to measure the velocities in the cardiac muscles and in the mitral or tricuspidal rings [10-12]. In cases of global or regional systolic dysfunction, the systolic velocity presents alterations. In the assessment of the diastolic function, the velocity of the rapid filling and atrial contraction phases may present alterations earlier than demonstrated from the mitral flow analysis.

Radioisotopic Ventriculography

The radioisotopic ventriculography was conducted at the department of nuclear medicine of the IMC, employing the in vivo labeling technique, i.e., 20 min after injection (of 12 mg of stannous pyrophosphate and 3.4 mg of stannous chloride diluted into 2 ml of saline) into the right cubital vein, 1111 MBq of sodium pertechnetate was injected, and then the images were taken. The images were obtained using a gamma camera (Millenium MPR, GE, USA), which was ECG gated (buffered beat averaging) using 32 frames per cardiac cycle. The camera was positioned in a left anterior oblique view (25 degrees) using an X-ray device with low energy and counting statistics of 200,000 counts per frame. At the beginning of each image acquisition, the computing system calculated the average duration of the RR intervals from the surface ECG for a time interval of T = 1 min. During the image acquisition, beats with positive or negative variations from this mean RR interval value must be less than 10%. The images obtained were processed in a computer (Entegra, GE, USA) equipped with a semi-automatic program capable of recognizing the edges of the ventricular cavities. The processing of the images followed the steps:

- spatial filtering;
- delimitation of the area of interest, which corresponds to the left ventricular cavity during the end of diastole;
- delimitation of the left ventricular cavity during the end of systole;

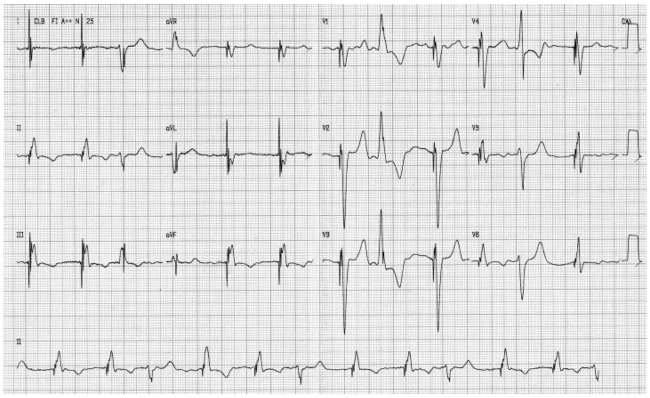

Figure 3. ECG 9 months after pacemaker implantation (October 26, 2000). Width of the QRS complex = 120 ms.

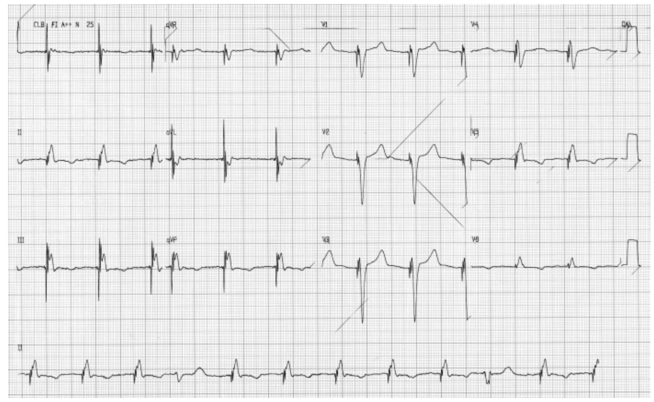

Figure 5. ECG 25 months after pacemaker implantation (March 4, 2002); width of the QRS complex = 100 ms.

- delimitation of an area adjacent to the left ventricular cavity at the moment of final systole, which was used for calculating the background radiation;
- obtaining the curves of maximal score corresponding to left ventricular diastole and systole in relation to time;
- calculation of the LV EF;
- obtaining the amplitude images; and
- obtaining the phase images and histogram.

The amplitude image allows the observer to determine which regions presented the best contractile performances. This is achieved by analyzing the largest or smallest displacement of the labeled red blood cells in each region of the LV, showing which region best contributes to the contractile performance of the LV. The phase image, together with the histogram, reveals the temporal sequence in which each region presents its contractile performance within the cardiac cycle, showing by means of colors if there is contractile synchronism between the atrial and ventricular cavities, between the right and left ventricular cavities, and between the walls of the LV, or if these regions present a disarrangement in their physiological contractile rhythm.

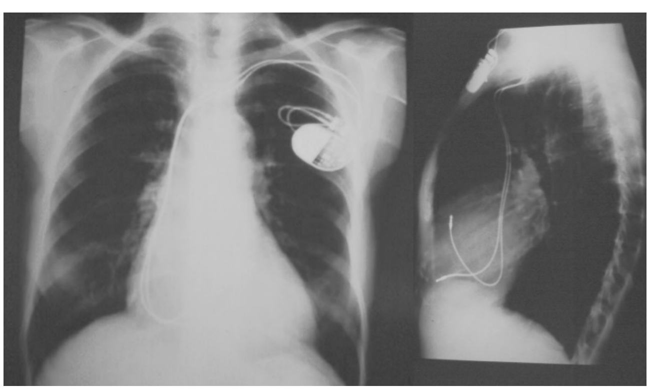

Figure 4. X-ray in the anterior and lateral view 9 months after pacemaker implantation (October 26, 2000).

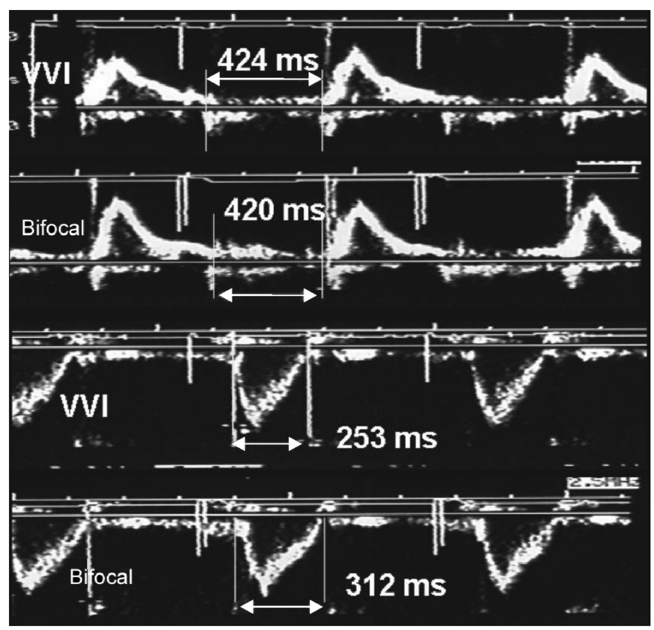

Figure 6. Spectral tracing of the curves of mitral and aortic flow (the two upper and two lower tracings, respectively) obtained with the pacemaker in the VVI and bifocal mode demonstrating the two measures obtained for the calculation of the Doppler-index (see Figure 1). A clear increase in the ejection time is observed for bifocal pacing, resulting in a decrease in the Doppler index from 0.68 to 0.35.

Results

Doppler Echocardiography

The electrocardiographic tracings (Figures 3, 4, and 5) performed in different periods after pacemaker implantation, showed a significant decrease in the QRS duration. No significant changes were observed in the EF (48%) or in the left atrium size; however there was a slight increase in CO (from 3.9 l/min to 4.06 l/min), in the rhythm movement of the LV posterior wall (from 15 mm/s to 39 mm/s), and a reduction of the Doppler-index from 0.68 to 0.35 from VVI to bifocal pacing (Figure 6). In addition, the mitral insufficiency area and the duration of mitral insufficiency were reduced with bifocal pacing from 1.2 cm^2 to 0.61 cm^2 (Figure 7), and from 170 ms to 85 ms, respectively. In the tissue Doppler of the LV-lateral wall no significant alterations were observed during the systolic phase, although the velocity of the rapid filling wave increased with activation of the pacemaker from 8 cm/s to 11 cm/s (Figure 8).

Radioisotopic Ventriculography

From radioisotopic ventriculography with bifocal stimulation (March 7, 2002), there is a clear rearrangement of the inter- and intra-ventricular contractile sequence, and also an increase in the EF value: during AF (14:14, EF = 27%), pacing in the RV outflow tract near the pulmonary vein (14:45, EF = 30%), pacing in the LV apex (15:15, EF = 30%), and bifocal pacing (15:45, EF = 39%, see Figure 9).

Discussion

Atrial fibrillation (AF) is the most common of the sustained arrhythmias, and it is associated with significant morbidity, mortality, and substantial cost to the health care industry. In fact, in the Framingham study, AF was considered a risk factor for death, regardless of the other cardiovascular conditions present [14]. If all the pharmacologic alternatives for treating AF do not provide the expected results, some interventional techniques are used such as focal ablation of the AF, surgery on the area of the heart causing the AF, specific atrial pacemaker implantation, and eventually, AV junction ablation with ventricular pacemaker implantation. Focal ablation for AF is being continuously developed; it will probably become one of the favored techniques in the near future. In this situation, the arrhythmia responsible for the onset of AF-extrasystoles and/or tachycardia of pulmonary veins, atrial tachycardia, or atrial flutter is eliminated or isolated through the application of radiofrequency using a catheter. Nevertheless, this technique is still undergoing investigation, and it depends on the evolution of specific leads to reduce the complications currently observed such as pulmonary vein stenosis. However, since it depends on thoracotomy and extracorporeal circulation, it is associated with high risk in patients suffering from decompensation, and it is generally a secondary procedure performed in association with other surgical corrections. The specific atrial pacemaker for AF (overpacing and/or biatrial) is still in the

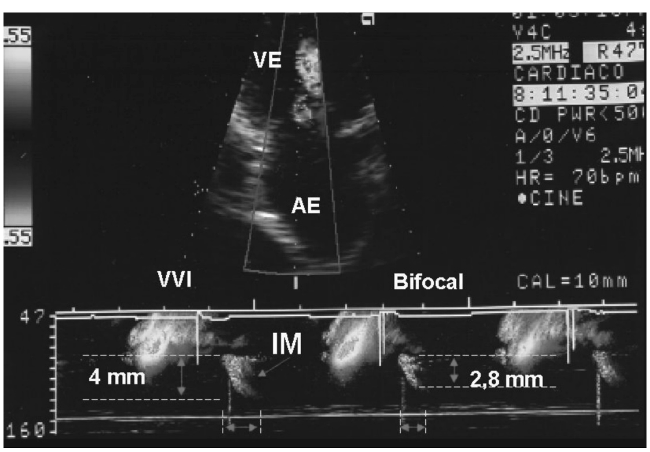

Figure 7. M-mode echocardiography, demonstrating the reduction in the duration of mitral backflow (IM), and its extension in the bifocal mode with respect to VVI mode.

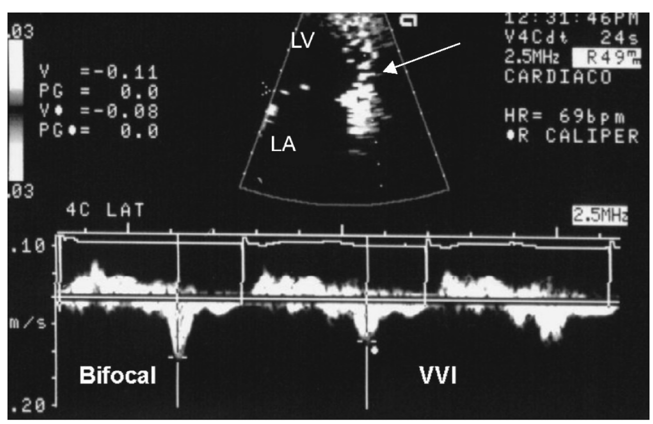

Figure 8. Spectral tracing of tissue Doppler echocardiography , with the sample in the basal lateral wall of the left ventricle (arrow) showing increase in the rapid filling wave in the bifocal pacing mode in relation to VVI mode. LV = left ventricle, LA = left atrium.

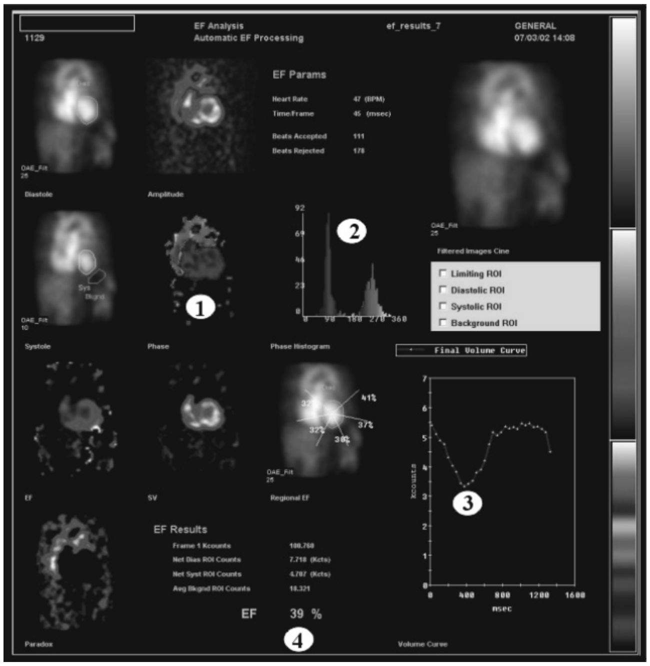

Figure 9. Typical ejection fraction (EF) analysis (Entegra, GE, USA) with radioisotopic ventriculography for bifocal stimulation. Phase image with analysis of the contractile temporal sequence (1), phase image histogram (2), curve of the radioactive activity over one heart beat (3), left ventricular ejection fraction = 39% (4).

process of development and investigation. The best results occur in cases of bradycardia-tachycardia syndrome with predominance of sinus rhythm, but it does not have application for chronic AF.

Catheter-induced ablation of the atrioventricular junction is the last and definitive therapeutic alternative for patients with symptomatic AF resulting from rapid ventricular response, whose arrhythmia is resistant to optimal drug therapy, or when drugs are not well tolerated. Frequently, these patients develop dilated cardiomyopathy as a result of the high heart rate, known as "tachycardiomyopathy." However, despite this, a large percentage of these patients progress to chronic AF [15]. The Canadian study using a physiologic pacemaker [16] showed that dual-chamber stimulation reduced the yearly incidence of development into chronic AF. Daubert and Mabo [17] believe that atrial stimulation may be useful for treating resistant forms of chronic AF and certain acute forms associated with high morbidity, e.g., during the postoperative period after heart surgery. The combination of beta-blockers with permanent atrial stimulation is a recommended alternative in special situations. Certain combinations may be analyzed to determine their adequacy in responding to CO. Ozcan et al. [18] showed that the regression of AF in patients treated with either atrioventricular node ablation or drugs is smaller than the expectancy for the general population. The long-term survival rate following ablation is not any different than the survival rate using medical therapy, and it is not evident that ablation and pacemaker implantation have adverse effects on survival, even without considering the occurrence of the multisite ventricular stimulation.

Several studies mention the potential benefits acutely produced by bifocal pacing on the index of the LV systolic and diastolic functions, in addition to electrocardiographic and clinical modifications of the patients [19,20]. Some echocardiographic parameters are being used in the assessment of these effects [10,21]. Saxon et al. [22] employed an index of systolic function (percentage of shortening of the transversal area) in which they observed an increase of 18% with the activation of a biventricular pacemaker. Pachon et al. [23] observed improvement in several echocardiographic indices by bifocal pacing, such as an increase in the EF (12.4%), in the CO (19.5%), and in the maximal velocity of rapid diastolic filling (31%), with a reduction in the left atrial area (11.9%), mitral insufficiency (32.3%), the A/E ratio (19.3%) and the duration of mitral flow (18%). More recently, Breithardt et al. [24] observed improvement in some echocardiographic parameters, including the index of myocardial performance (from 1.21 ± 0.51 to 0.85 ± 0.34), with the activation of the biventricular pacemaker. The tissue Doppler also proved to be an excellent method for assessing the biventricular pacemaker [25], indicating improvement of the electromechanical delay and the increase in the systolic motion of the walls.

Case Report

Bifocal pacing enabled us to verify the elevation in the CO, in the cardiac performance rate, and in the velocity of the rapid filling in the tissue Doppler of the LV lateral wall, reproducing some of the pacemaker's benefits on the behavior of the systolic and LV diastolic function. The absence of alterations in some parameters, e.g., the EF, does not exclude the benefit produced by bifocal pacing. This may be a result of the limitation of the M-mode in the calculation of the EF, which includes only the septal and

lower-lateral basal portions in the calculation of the global volume of the LV, excluding the potential benefit of bifocal pacing on other walls of the LV.
According to "Guidelines for the Diagnosis and Treatment of Heart Failure from the Brazil Cardiac Society" [26], the terminal state of most cardiopathies is a major public health problem because of their increasing prevalence, with high morbidity and mortality rates (about 10% for the non-selected population and 30% for patients with a NYHA class IV, who were adequately treated in our setting [26]).

Conclusion

According to the data from the Brazilian Health Department registry, there are already two million patients suffering from heart failure, and there is an incidence of 240,000 new cases a year. Since the pilot studies have shown promising results, a number of long-term studies are now being undertaken to assess the variety of medications and hospital treatments for heart failure. Until definitive results from these studies are available, none of these interventions can be recommended for routine use in patients suffering from heart failure.

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