Intramyocardial Electrograms in the Evaluation of Biventricular Pacing for Dilated Cardiomyopathy - A Case Report

J. R. SANT´ANNA, J. BARBISAN, R. KALIL, I. NESRALLA
Instituto de Cardiologia do Rio Grande do Sul, Porto Alegre, Brazil

P. KASTNER, H. HUTTEN
Institute of Biomedical Engineering, University of Technology, Graz, Austria

M. SCHALDACH
Institute of Biomedical Engineering, University Erlangen-Nuremberg, Erlangen, Germany

Summary

Biventricular pacing represents an additional treatment in heart failure secondary to dilated cardiomyopathy. One indicator that this treatment is effective is the decrease in duration of the QRS complex. Intramyocardial electrograms (IEGMs) were obtained during biventricular pacing with leads implanted in the coronary sinus and in the right ventricle. A methodology for analysis and presentation of IEGMs has been established. A 64-year-old patient with dilated cardiomyopathy, atrial fibrillation, and intraventricular block, received a pacemaker system consisting of a Physios CTM01 dual-chamber pulse generator and two fractal-coated leads: a right ventricular endocardial lead model PX60BP and a coronary sinus (left ventricular vein) lead model V336. The lead in the coronary sinus (in the coronary vein) was connected to the ventricular channel, and the lead in the right ventricle was connected to the atrial channel. The pacemaker was programmed in DDT mode with an atrioventricular delay of 15 ms. IEGMs were recorded as ventricular evoked responses (VER) and crossed ventricular evoked responses (VERX). Parameters that were considered in VERX analysis were the interval between the stimulus at one electrode and the occurrence of the maximum negative slope in the other, the duration of the VER, considered as the interval between the stimulus and the end of repolarization, and the the maximum slope during the depolarization phase. During sequential evaluations, the maximum slope during the depolarization phase increased, thus indicating both a reduction in ventricular size and improved cardiac dynamics. Potential diagnostic benefits of IEGM during biventricular stimulation will be defined as medical experience accumulates.

Key Words

Dilated cardiomyopathy, biventricular pacing, intramyocardial electrogram

Introduction

The multisite pacing of the heart has been used to treat congestive heart failure secondary to dilated cardiomyopathy and associated with intraventricular conduction block [1,2]. The shortening of the ventricular depolarization time secondary to simultaneous biventricular stimulation is correlated with the acute benefit observed in the left ventricular function and seems an important determinant for the satisfactory short-term clinical results of this therapy [3,4,5].

Synchronous atrio-biventricular pacing is the pacing mode indicated for patients with normal sinus function (and stable atrium), and is an ideal condition if the ventricular pacing stimulus is transmitted by transvenous leads implanted in the interventricular septum and in a left ventricular cardiac vein (implanted through the coronary sinus). Alternatively, electrodes may be implanted at the left epimyocardial surface or in the right ventricular outflow tract. Pulse generators with the capability of multifocal pacing are available, allowing optimization of the sequence of cardiac depolarization. Conventional dual-chamber pulse generators (DDD) may be used for this purpose by splitting the ventricular channel in order to pace both ventricles at the same time. Atrial fibrillation implies an isolated biventricular stimulation, often accomplished by using both channels of a DDD pacemaker programmed with a very short or zero atrioventricular delay. This is a favorable alternative to splitting the output of a single-chamber pulse generator, since individual focal stimulation is then possible. The connection of each ventricular lead to the individual channels of a DDD pacemaker allows all capabilities of the pulse generator to be used.

A DDD pulse generator capable of telemetrically recording the intramyocardial electrogram in the atrial and ventricular channels was used to provide multisite biventricular pacing in a patient with dilated cardiomyopathy, atrial fibrillation, and intraventricular conduction block. Our objectives were to confirm the capability of the implanted transvenous coronary sinus lead (positioned in a cardiac vein) to acquire a stable and adequate electrogram and also to establish a methodology for evaluation of biventricular pacing using IEGMs.

Materials and Methods

The patient considered for the study was a 64 year-old male who complained of dyspnea and fatigue even after receiving maximum drug therapy (digitalis, diuretics and vasodilators). In addition, he had a history of multiple previous hospitalizations due to congestive heart failure. He was classified as NYHA functional class III.

The conventional electrogram showed atrial fibrillation associated with low ventricular response and intraventricular conduction disturbances (QRS duration of 160 ms). The thoracic X-ray revealed severe cardio megaly and mild pulmonary congestion. Echocardiographic findings were low ejection fraction (34 %), left atrial enlargement, and an increase in the systolic and diastolic diameters of the left ventricle.

Pacemaker therapy was considered for optimization of heart rate, which was slow and irregular due to atrial fibrillation and use of digitalis. The patient suffered from congestive heart failure, enlarged left ventricle, and intraventricular block. As these are accepted criteria for biventricular pacing, this form of pacing was considered.

The transvenous pacemaker implant was performed under local anesthesia and fluoroscopic control. The right cephalic vein was dissected and the transvenous electrodes were advanced into the right atrium. The PX60BP fractal lead (Biotronik, Germany) was positioned in the endocardium of the interventricular septum and electrophysiological measurements were performed. The V336 coronary sinus fractal lead (Biotronik, Germany) was introduced in the coronary sinus and advanced into a lateral vein of the left ventricle. Electrophysiological evaluation was performed and secure lead fixation was assured. The test of biventricular pacing included an observation of QRS complex shortening [4]. Leads were connected to the Physios CTM01 pulse generator (Biotronik, Germany) in the following configuration: the transvenous endocardial septal electrode was connected to the atrial channel, and the coronary sinus electrode was connected to the ventricular channel. The pulse generator was placed in a subcutaneous pocket in the right pectoral region and the incision was sutured. The pacemaker was then programmed in DDT mode with a pulse rate of 75 ppm and an atrioventricular interval of 15 ms, which is the lowest possible atrioventricular interval.

The patient was discharged from the hospital 48 hours after pacemaker implantation. Pre-operative medication was maintained. A follow-up program with periodic clinical, radiological, and echocardiography evaluations and IEGM recording was established. In the Doppler echocardiography evaluation, the cardiac output, left atrial diameter, systolic and diastolic ventricular diameter, and cardiac output at 5-minute intervals in the right ventricular, left ventricular and biventricular pacing modes, were evaluated. IEGMs were recorded via telemetry in different pacing modes.

Cardiac electrical signals considered were those related to the spontaneous cardiac rhythm, the spontaneous action potential (SAP), and the ventricular evoked response (VER; see Table 1). When the ventricles were stimulated by one lead and the resulting signal from ventricular depolarization was registered by the other lead, this signal was considered as a crossed ventricular evoked response (VERX; see Table 1).

For the analysis of the signals, special consideration was taken to the VERX and its parameters:

- VERX-tX(AV) (ms): the interval between the stimulus at the atrial channel and the occurrence of the maximum negative slope at the ventricular channel (or analogously with the chambers reversed). In this particular patient, VERX-tX(AV) corresponds to right-ventricular pacing and left-ventricular (coronary vein) sensing, and VERX-tX(VA) corresponds to the inverse config-

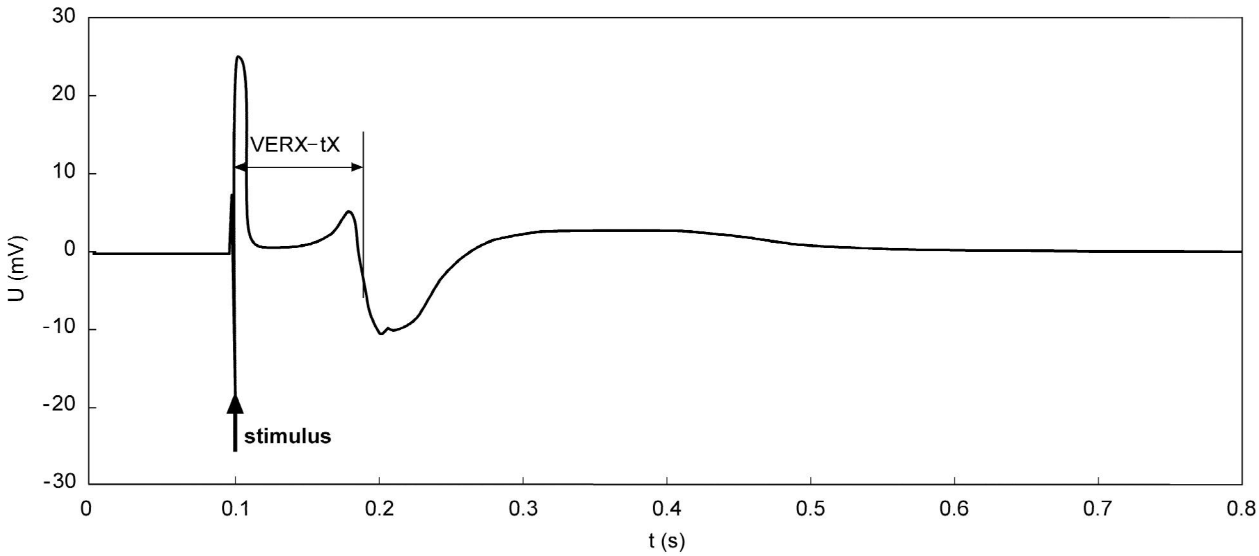

Figure 1. Crossed ventricular evoked response (VERX) and definition of VERX-tX.

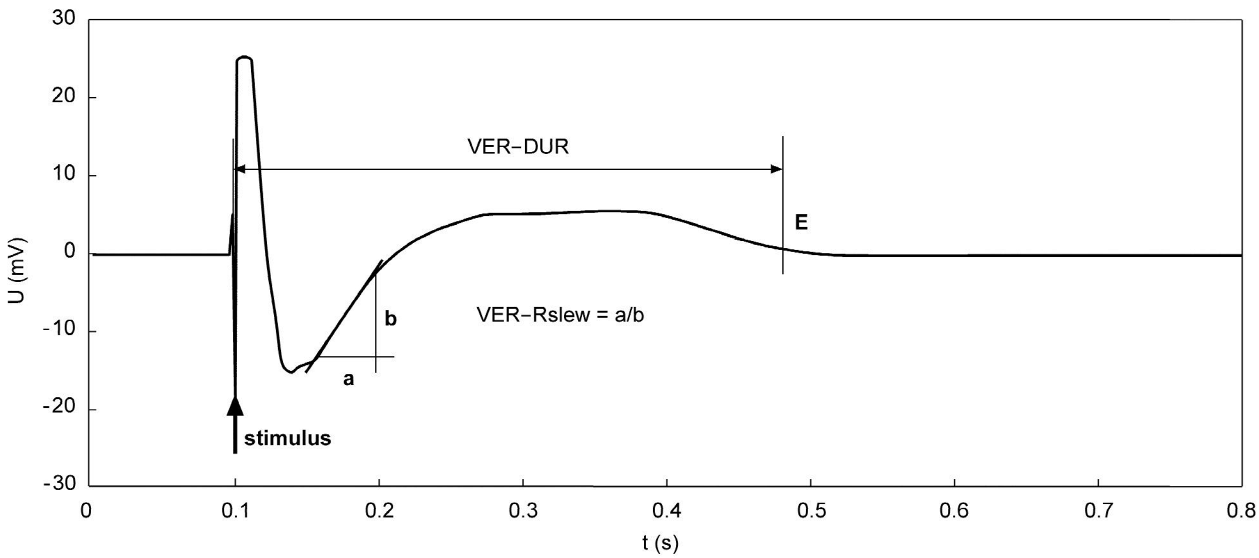

Figure 2. Ventricular evoked response (VER) and definition of VER-DUR and VER-Rslew.

uration. Figure 1 illustrates VERX and the definition of parameter VERX-tX.

- VER-DUR (ms): the duration of the VER, measured as the interval between the stimulus and the end of repolarization.
- VER-Rslew (mV/s): the maximum slope during depolarization phase. Figure 2 illustrates the definition of VER-DUR and VER-Rslew.

Three to five minutes stimulation in different pacing modes, echocardiography evaluation and signal recording using a laptop (for 1 minute interval) were performed. Signal records were sent to Cortronik (Graz, Austria), via the Internet for signal processing. After data transfer, reports with processed data were available in less than 24 hours.

Results

IEGMs resulting from the lead being positioned in a left ventricular vein were clear, stable, and satisfactory

Parameter	Signal type	Pacing channel	Recording channel
VERX_tX (VA)	VERX	Vent. (left)	Atr. (right)
VERX_tX (AV)	VERX	Atr. (right)	Vent. (left)
VER_Rslew (A)	VER	Atr. (right)	Atr. (right)
VER_Rslew (V)	VER	Vent. (left)	Vent. (left)
VER_DUR (A)	VER	Atr. (right)	Atr. (right)
VER_DUR (V)	VER	Vent. (left)	Vent. (left)

Table 1. Parameter code.

for analysis. Signals obtained from this electrode, from the right (septal) ventricular electrode and both together contributed to the development of a methodology for the electrocardiography evaluation of multisite stimulation of the heart.

Minor differences were observed between VER-tX(AV) and VER-tX(VA) (87.5 ms and 90.5 ms in the first evaluation, and 93.5 ms and 92.0 ms after 12 months, respectively).

The VER-DUR was shorter for left ventricular stimulation than with pacing from the right ventricular electrode: VER-DUR(A), originating in the right ventricle, was 400.6 ms after implant and 383.2 ms one year later. For the same period, the VER-DUR(V) that originated in the left ventricle was 390.7 ms and 340.2 ms, respectively.

The values of the parameter VER-Rslew associated with right ventricular pacing (VER-Rslew(A)) were smaller than those recorded at the left ventricular lead (VER-Rslew(V)): respectively 195.0 mV/s and 310.1 mV/s after implant and 281.4 mV/s and 446.0 mV/s one year later. Table 2 illustrates some values obtained during pacemaker evaluation.

An example of the study report can be seen in Figure 3. During sequential evaluations a slight decrease of VER-DUR and an increase of VER-Rslew can be observed.

From a clinical point of view, the patient presented a reduction of symptoms during follow-up, and the radiological signals of heart failure disappeared.

Discussion

Fractal electrodes can record IEGMs with high resolution and signal quality using an implantable pacemaker. The acquired intrinsic cardiac signal is recognized as a spontaneous action potential, and the signal resulting from the pacemaker stimulus is recognized as the evoked action potential; if the signal originates in the ventricle, it is designated as VER. Modifications in electrograms can be related to changes in the myocardial condition secondary to inotropic and chronotropic interventions [6]. A correlation was established between the IEGM and an inflammatory response of the myocardium, as seen in acute rejection episodes of transplanted hearts. A system called Computerized Heart Allograft Recipient Monitoring (CHARM), which consists of an implantable pacemaker (Physios CTM01), a programmer, and tailored software for processing the signals recorded telemetrically, is already in clinical use, representing a helpful tool in the management of patients who receive a cardiac transplant [7].

Several supporting factors indicate that the VER and its parameters reveal modifications in ventricular geometry, thus instantaneously reflecting actions that affect the cardiac dynamics; this was observed in one study that compared clinical records of VER and computer models of the heart [10]. Such findings were con-

	VERX_tX (AV) (ms)	VERX_tX (VA) (ms)	VER_DUR (A) (ms)	VER_DUR (V) (ms)	VER_Rslew (A) (mV/s)	VER_Rslew (V) (mV/s)
8/1999	87.5	90.5	400.6	390.7	195.0	310.1
9/1999	90.5	92.0	401.3	385.1	236.6	370.6
4/2000	92.0	93.5	406.6	388.3	223.2	347.5
9/2000	93.5	92.0	383.2	340.2	281.4	446.0

Table 2. Analysed parameters of the VER in the course of time.

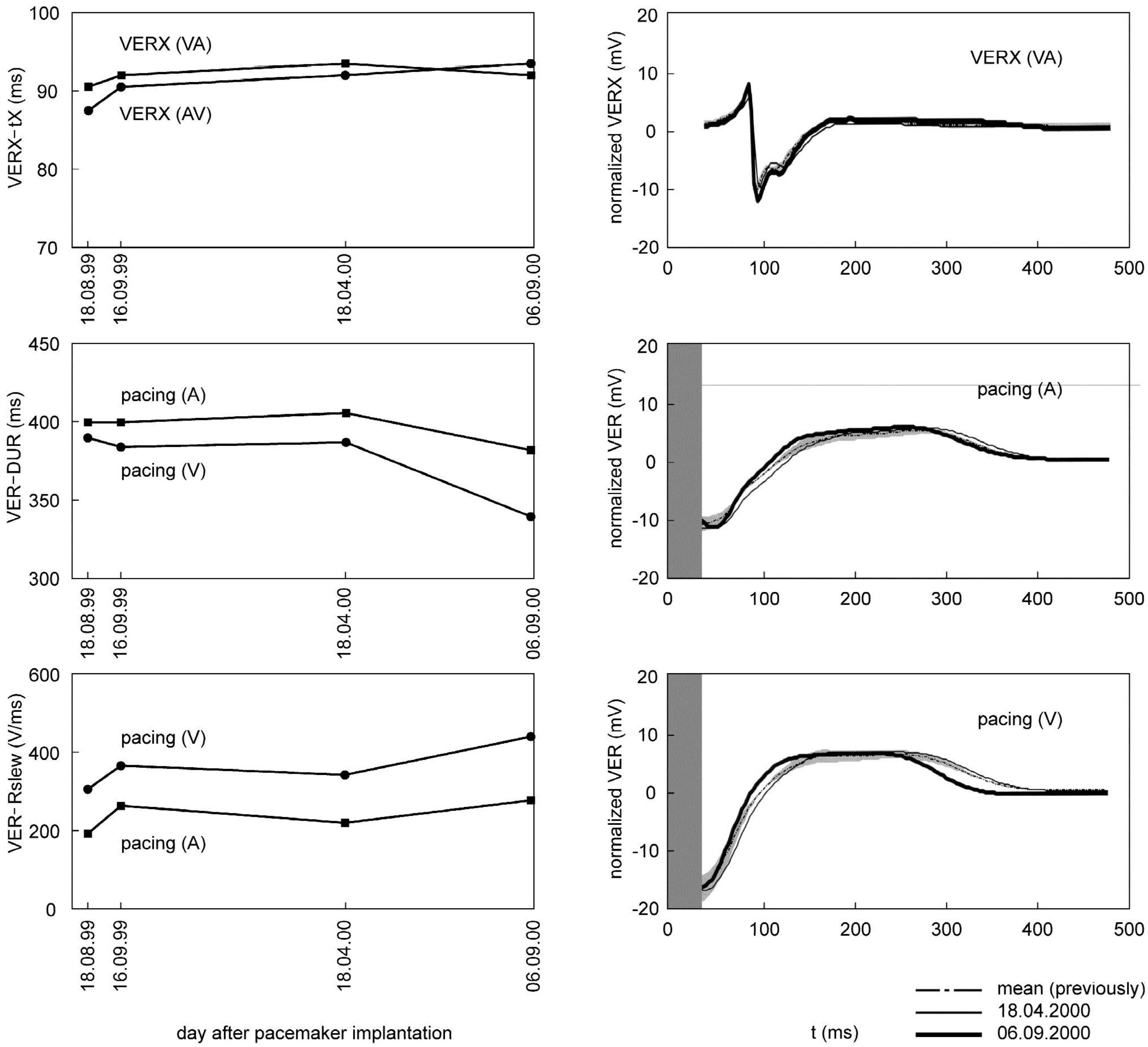

Figure 3. Illustration of a recent report, with indications of VERX-tX, VER-DUR and VER-Rslew. On the left-hand side, the trend curves of the parameters are displayed. On the right-hand side, the signal morphology of the most recent recording of each signal type are shown in comparison to previous recordings.

firmed in a subsequent clinical study considering effects of heart rate and body position in patients who underwent heart transplantation [11]. However, up to now, clinical studies concerning acute and chronic modifications of IEGM in relation to dynamic characteristics of autologous hearts have been limited to the use of Physios CTM pacemakers in patients with hypertrophic obstructive cardiomyopathy [8].

The ability of the Physios CTM 01 pulse generator to monitor IEGMs, the existence of a methodology to record and analyze the cardiac signals, and the possibility of monitoring hemodynamic modifications encouraged us to implant the device in patients with indications for isolated biventricular stimulation. Additional requirements were:

- the possibility of biventricular stimulation with a

DDD pacemaker that stimulates with a short or zero interval between sequential pulses (DDT mode and AV interval of 15 ms are possible in the Physios CTM) and
- the potential for the pacing to modify the condition of the myocardial fiber in different pacing modes, in a short period of time (the observed improvement of left ventricular performance is secondary to biventricular pacing) [9].

It should be recalled that the IEGM is extremely sensitive to several influences. The VER is altered by chronic and acute interventions in the cardiovascular system, and such effects should be minimized during the study. A strict research protocol was followed. Drug prescriptions, time, environmental factors, and technical personnel were maintained wherever possible for the evaluations. However, it should be noted that the results of sequential studies may be less precise than those obtained from acute evaluations of the effects of different interventions upon the VER.

There may be concern about recording an IEGM using a coronary sinus lead (which has no active fixation or direct contact with myocardial fibers, but is impacted in the cardiac vein and isolated from cardiac fibers by the venous wall). The present clinical case demonstrates that signals of high quality can be obtained with the fractal surface of the cardiac vein electrode using the telemetry of the Physios CTM01.

Different types of signals could be registered with stimulation and/or monitoring of myocardial electrograms in the atrial and ventricular channels, or both. This provided the opportunity to differentiate right ventricular (septal), left ventricular, and biventricular stimulation in terms of electrocardiography. Out of the different possibilities of obtaining IEGMs, we selected for this study the crossed ventricular evoked response (VERX), a signal obtained from electrodes implanted in different sites in the left and right ventricle. One of the electrodes was used to stimulate the heart and the other to sense its electrical activity (and vice versa). VERX has been studied less compared to other electrograms, but there is evidence that it may represent important information, e.g. the excitation propagation time, which is related to the velocity of the depolarization wave front. From these IEGMs, the following parameters were selected for evaluation: 1) propagation time (VERX-tX), related to the velocity of excitation propagation in the heart; 2) duration of the evoked potential (VER-DUR), corresponding to the QT-interval calculated during spontaneous cardiac rhythm; and 3) maximum inclination of the depolarization slope (VER-Rslew), inversely related to the end-diastolic size of the ventricles [10].

The hypothesis that the VER-Rslew parameter may increase with the decrease of the ventricular diameter, as the heart remodulates during chronic biventricular pacing [11], was confirmed in this particular patient. This effect was not restricted to biventricular stimulation, but also to left ventricular stimulation, which compared favorably with the right ventricular stimulation (Figure 3).

Sequential changes in VERX-tX secondary to modifications in shape and size of the heart, as assessed by VERX, were not found. The myocardial propagation time may correlate with the size of heart, and is probably also inversely related to the extent to which the myocardial fibers are stretched. A large number of observations, made over a considerable period of time and including a considerable number of patients, will be necessary to investigate this hypothesis.

This case illustrates the use of IEGM (specifically of the VER and VERX signals) to monitor modifications in the morphology of the heart in one patient with dilated cardiomyopathy who was submitted to isolated biventricular stimulation. Some parameters of VER and VERX were identified that may become useful as complementary information in the monitoring and management employing this mode of cardiac pacing. The Physios CTM01 pacemaker can be implanted in patients with dilated cardiomyopathy and atrial fibrillation, when isolated biventricular stimulation is advocated. A large group of such patients, in a close follow-up program, will bring a large amount of data and provide information to support our initial observations.

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Contact
Joao Ricardo M. Sant’Anna, MD
Instituto de Cardiologia do Rio Grande do Sol
Brazil
Telephone: +55 51 230 3600
Fax: +55 51 217 1358
E-mail: tofani@ez-poa.com.br