Clinical Assessment of the Correlation Between Right Ventricular Impedance and Left Ventricular Contractility

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Summary

Variation in the right ventricular impedance (RVI) generated by changes in the myocardium-to-blood ratio during systole is the signal used for Closed Loop Stimulation form of rate-responsive pacing, which integrates the pacemaker into the natural cardiovascular control loop. Two previous studies have demonstrated that RVI variations are well correlated (r > 0.91) to the variation in right ventricular contractility. The aim of this study was to assess whether a correlation even exists between RVI and left ventricular contractility, which is the main factor in hemodynamic performance. In 15 consecutive patients all of whom showed no evidence of conduction disturbances, RVI and the maximum pressure change (dp/dt_{max}) in the left ventricle were recorded during diagnostic left heart catheterization. During the procedure, the two parameters were simultaneously measured during an isometric exercise test and left ventriculography, and the variation trends were compared. After the handgrip test, the correlation between variations of RVI and left ventricular dp/dt_{max} was acceptable (r > 0.79). As peripheral vascular resistance and left ventricular afterload increases due to the stress, the sympathetic response influences the contractile status of both ventricles simultaneously; this accounts for the RVI correlation with right ventricular dp/dt_{max} as previously found by our study group as well as other authors. Left ventriculography affects the preload by increasing the left ventricular diastolic filling during the isovolumetric ventricular contraction. These changes are shared by the right ventricle, accounting for the strong correlation (r > 0.92) found between the RVI and left ventricular dp/dt_{max} during this test. The results of this study demonstrate that the device responds properly to the variation of contractility in the whole heart.

Key Words

Intracardial impedance, myocardial contractility, rate-modulated pacing, handgrip, left ventriculography

Introduction

Conventional dual chamber rate-adaptive pacing is the treatment of choice whenever the patient's chronotropic competence is severely impaired. In currently available DDDR devices, the appropriate modulation of the heart rate depends on the degree to which the artificial rate control algorithm approximates the physiological response and, therefore, on the specificity of the signal detected by the sensor. The control system continues to be the main limitation of all rate adaptation approaches. All of these systems operate in open loop control or, at best, as with the evoked QT sensor, in closed loop control with positive feedback. Operating in open loop control means that the device is unable to verify whether the actual paced rate is appropriate to the patient's metabolic needs and his or her general pathophysiologic status, or, on the other hand, whether it induces side effects (e.g. an improper increase of arterial blood pressure) that are not well tolerated [1-3].

In descriptions of currently available devices, the concept of Closed Loop Stimulation (CLS) with negative feedback, driven by variations in cardiac contractility, is suggested as a system capable of controlling the pacing rate while adapting to the real hemodynamic needs of the patient and, consequently, improving his or her

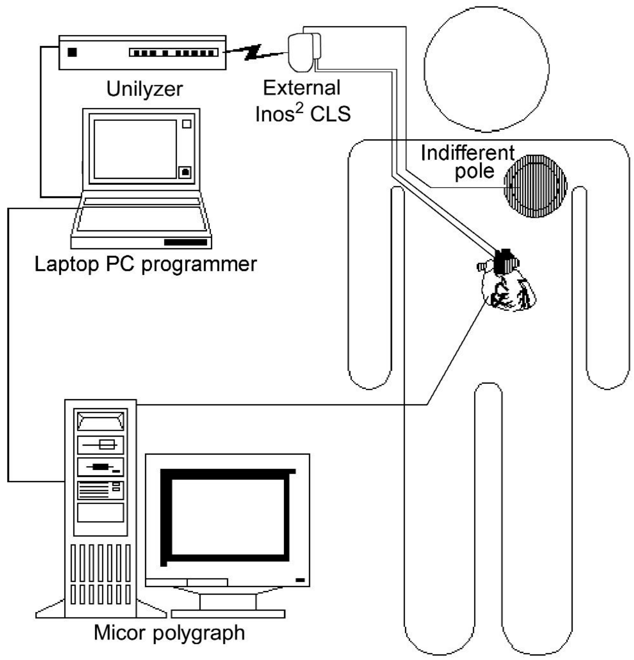

Figure 1. Measuring system array for simultaneous recording of right ventricular impedance by an external Inos[2] CLS pacemaker and of the maximum pressure change in the left ventricle (dp/dt_{max}) by the MICOR Polygraph.

quality of life [1-11]. The role of Closed Loop Stimulation is to maintain appropriate cardiovascular regulation by integrating the implanted device into the natural system. Closed loop pacing can be accomplished by converting changes in myocardial contractility into individualized pacing rates. With such a device, the pacing rate is linked to the circulatory centers, and adequate perfusion is provided under various conditions.

The Inos CLS pacemaker family (Biotronik, Germany) uses an algorithm based on variations in the right ventricular impedance, which is generated by changes in the myocardium-to-blood ratio in the area around the tip of a conventional ventricular pacing lead during systole. A sub-threshold test signal is applied between the ventricular tip and the pacemaker housing during a 250 ms time window that begins 50 ms after the ventricular pacing pulse. The impedance measured by the signal, which correlates directly to the right ventricular maximum pressure change (RV dp/dt_{max}), is governed by negative feedback and is converted into a closed loop rate control [4-6]. Thus, if the pacing rate is set to a value that is too high, the baroreceptors detect the excessive increase in blood pressure. This leads to an immediate negative regulation of contractility and, consequently, to a reduction in the pacing rate. Unlike non-closed-loop DDDR systems, the CLS mode has demonstrated its ability to modulate the heart rate not only in response to physical activity, but also in response to other non-voluntary stress situations (mental stress [3,12], drug infusion [12,13] and circadian variations [12,14]), along with re-establishing the baroreceptor response to the Valsalva maneuver [15]. A superior quality of life was also observed for patients using the CLS system [16].

The only argument that can be made against the CLS system is that the device measures the intracardial impedance in the right ventricle, with no direct evidence that the control signal is correlated to left ventricular contractility, which is the main factor in the hemodynamic performance of the patient. The aim of this study was to assess whether the variations in intracardiac impedance measured in the right ventricle (RVI) are also well correlated to variations in of the maximum pressure change collected in the left ventricle (LV dp/dt_{max}), which is considered the most important parameter in evaluating myocardial contractility.

Materials and Methods

In 15 consecutive patients without conduction disturbances (nine males and six females, mean age 62.8 years), but who were suspected carriers of a coronary artery or valvular pathology, the RVI, telemetrically detected by an exteriorized pacing system, was measured simultaneously with the LV dp/dt_{max} during diagnostic left-heart catheterization. The RVI was collected while pacing the patient in VDD mode using an exteriorized Inos[2] CLS pacemaker connected to two temporary bipolar leads (atrial J-shaped and ventricular) and to a large-surface external electrode pad simulating the pulse generator case (indifferent electrode). The intraventricular pressure was recorded using a 6 French pig-tail pressure catheter positioned in the left ventricle. The LV dp/dt_{max} value was continuously calculated by means of a hemodynamics polygraph Micor (Siemens, Germany) The measuring system is depicted in Figure 1. All signals were stored on a computer for analysis by Mathcad (MathSoft, USA) and Statistica (StatSoft, USA), which are common mathematical and statistical software.

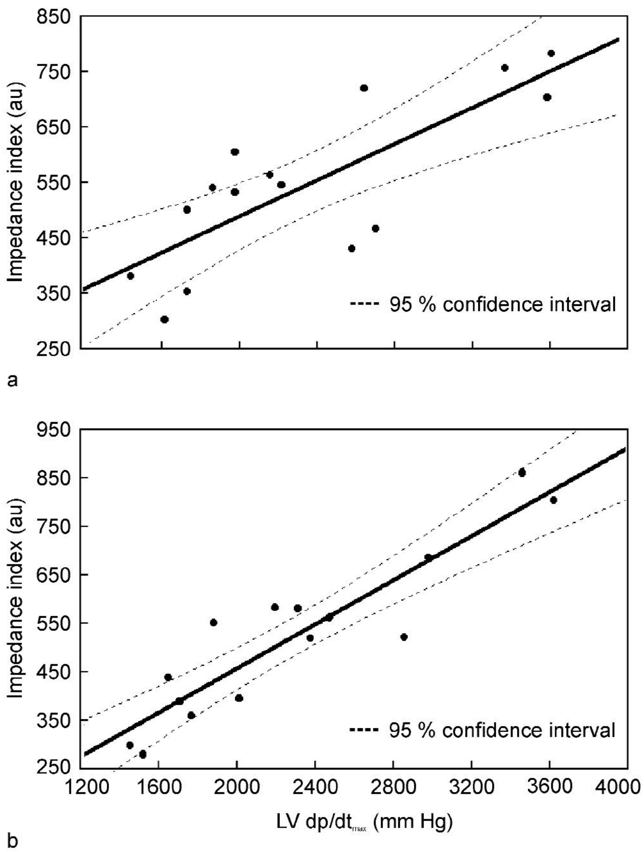

Figure 2. Correlation between maximum pressure change in the left ventricle (LV dp/dt$_{max}$) and an impedance index which reflects the myocardial contraction dynamics. The impedance index is measured in arbitrary units (au) in the right ventricle before and after handgrip (a) and before and after ventriculography (b), using the external device programmed to the DDD mode.

Results and Discussion

During the procedure, the two parameters were simultaneously measured in the patient's baseline condition, before and after the isometric exercise test (handgrip at 80 % patient capability) and during left ventricular angiography (ventriculography). The trends of variation were then compared. During the handgrip test, the correlation between the variations in the RVI and LV dp/dt$_{max}$ was acceptable ($r > 0.79$) (Figure 2a). This type of stress, limited by the patient's individual capabilities, increases the peripheral vascular resistances and left ventricular afterload. The sympathetic response to isometric stress influences the contractile status of both ventricles simultaneously. Since the RVI is measured in the right ventricle, this accounts for the better correlation between this index and variations of the RV dp/dt$_{max}$ found by our group ($r > 0.91$) during the VICRA (Validation of Inos Contractility Rate modulation Algorithm) study [11] and by Osswald et al. ($r > 0.95$) in a previous investigation performed during dobutamine stress test [6].

In contrast to the handgrip test, left ventriculography affects the preload by increasing the left ventricular diastolic filling during the isovolumetric ventricular contraction. These changes are shared by the right ventricle, accounting for the good correlation ($r > 0.92$) between the RVI and LV dp/dt$_{max}$ found during this test (Figure 2b). The results shown above are particularly significant because the entire population of 15 patients that participated in the study was affected by ventricular dysfunction or coronary artery disease that could affect their inotropic response.

Conclusion

Sensor-free Closed Loop Stimulation is a significant step ahead in preserving the patient's intrinsic circulatory regulation, and, consequently in maintaining the patient's correct hemodynamic balance in any situation in accordance with his or her general health status. Closed Loop Stimulation integrates the pacemaker into the physiological control system, enabling the heart rate to be controlled by the autonomic nervous system and not by an artificial pacing algorithm. The results of this study are meaningful because they demonstrate that the device responds properly to the variations in contractility throughout the entire heart and not just in the right ventricle. This and other clinical experiences show that Closed Loop Stimulation as a therapeutic tool is not expected to be limited to the treatment of chronotropic incompetence [7, 8]. Potential future indications for Closed Loop Stimulation include malignant vasovagal syncope [17-20] and monitoring of the sympathetic activity in order to tailor antiarrhythmic therapy.

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