Improving Cardiac Performance by Restoring Chronotropic Competence through Closed Loop Stimulation - A One-Case Report

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Summary

This article presents the results gained from a patient who was implanted with a dual-chamber pacemaker that possesses the capability of using information from the body's natural closed loop (INOS² CLS, BIOTRONIK) for rate adaptation. Thorough testing before implantation showed the patient to be chronotropically incompetent with concomitant cardio-pulmonary diseases. Sick sinus syndrome with intermittent sinus arrest (interruptions lasting up to 8.7 sec) and chronotropic insufficiency caused a low output and a developing congestion and left-heart insufficiency. At the 3-month post-implantation follow-up, these earlier tests were repeated and additional tests that were appropriate for determining chronotropic competency were performed (i.e., during sleep, exercise, and mental stress). The results and the subjective reports from the patient indicated that quality of life was improved and chronotropic competence was restored through Closed Loop Stimulation.

Key Words

Closed Loop Stimulation, sick sinus syndrome, rate adaption, cardiac insufficiency, chronotropic incompetence

Introduction

Lacking rate adaptation with chronotropic incompetence as a result of sick sinus syndrome includes reduced cardiac performance and signs of left-heart insufficiency. For patients in whom the right heart is additionally strained (e.g., due to an extant pulmonary disease), this leads to cardiac decompensation in the sense of a globally decompensated cardiac insufficiency with limiting shortness of breath at rest and sometimes immobility.

Closed Loop Stimulation provided by the INOS² CLS (BIOTRONIK) - a rate-adaptive cardiac pacemaker system - can re-store chronotropic competence by using information from the intrinsic cardio-circulatory closed loop and can adapt the circulatory parameters to the current needs of the body [3]. The following article will discuss how this method is effective under load, during sleep and during mental stress in a younger, but nevertheless multimorbid chronotropically incompetent, female patient.

Materials and Methods

The patient (53 years of age, female) was hospitalized for the past 6 months with shortness of breath (dyspnea) under low levels of load (NYHA Class III) and seriously reduced cardiac performance. Anamnesis included: chronic obstructive pulmonary disease (COPD), heavy cigarette smoking, indications of sleep-apnea syndrome, and metabolic dysfunction. The cardio-pulmonary, noninvasive, and invasive examinations (Table 1) were oriented toward the cardinal symptoms.

The left part of Figure 1, shows the thoracic x-ray picture immediately taken after patient incomming. From that x-ray stress of right and left heart was diagnosed. The multicausal therapy introduced was prioritized according to the urgency of the diagnosis. With sinus arrest lasting up to 8.7 sec and the suspicion of chronotropic incompetence as a result of sick sinus syndrome, a dual-chamber cardiac pacemaker system was implanted (INOS² CLS, BIOTRONIK). Felodipine (10 mg) and isosorbide dinitrate (120 mg) were admin-

Examination	Results	Diagnosis
Biometry and lab test	162 cm; 105 kg; increased levels of: blood sugar, cholesterol and triglyceride	Metabolic dysfunction
Right cardiac catheter	Pulmonary-arterial pressure gradient 70 mmHg	Congested lung
Body plethysmography	IVC: 2.54 l; FEV: 1.54 RAW_{ToT}: 0.67 kPa/l*s	COPD
Polysomnography	Mean basal satiation: 81%; Lowest basal satiation: 51%	Obstructive sleep-apnea syndrome
X-ray of the thorax	Widened right ventricle; decreased parahilar transparency	Cardiac insufficiency
Left cardiac catheter	Hyperthophic left ventricle, normal contractility	Left-heart hyperthrophy, arterial hypertension
24-hour Holter ECG	Sinus arrest; interruptions lasting up to 8.7 sec.	Sick sinus syndrome, chronotropic incompetence

Table 1. Cardio-pulmonary, noninvasive, and invasive examinations aimed at the leading symptoms of the patient.

istered. Due to the onset of cardiac decompensation, treatment for the obstructive sleep-apnea syndrome had to be delayed until a later time.

At the 3-month follow-up examination (post-implantation), we repeated the noninvasive examinations and additionally performed the following tests that are suitable for indicating restored chronotropic competence:

- Bicycle ergometry for determining levels of lactate in the capillary blood in the range of physical load [1]
- Polysomnography for proving rate adaptation during the different phases of sleep [4]

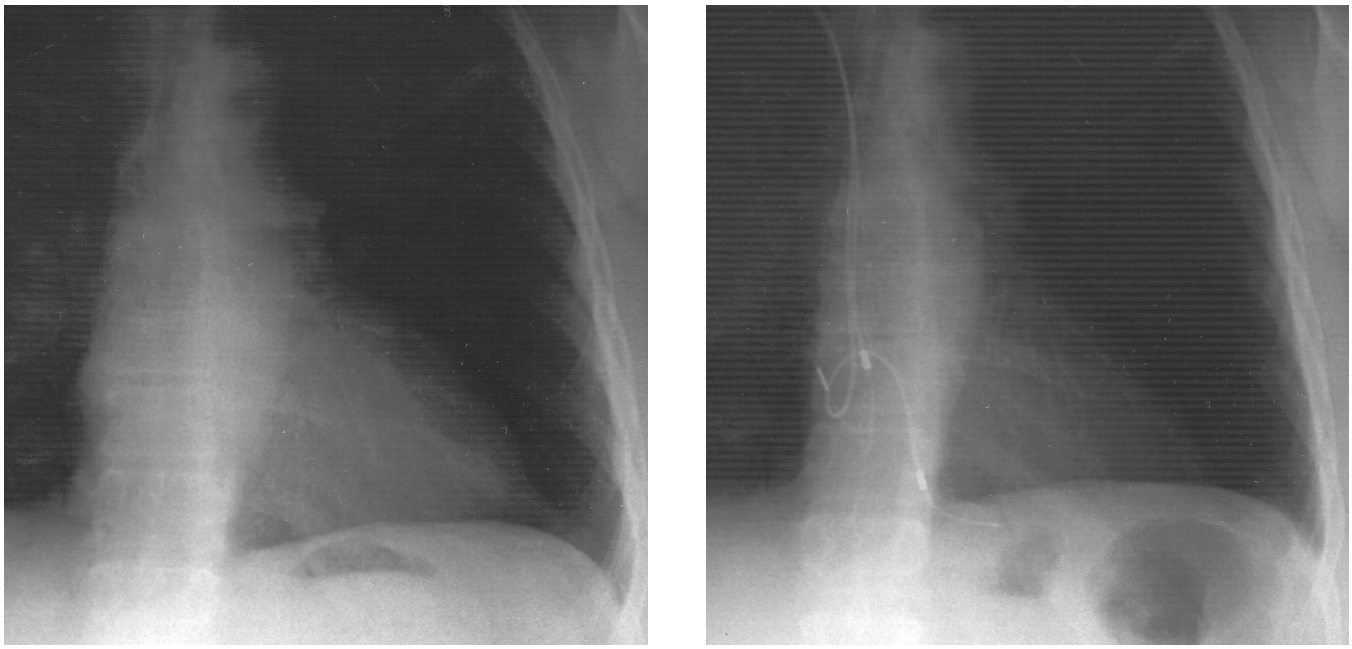

Figure 1. Thoracic x-ray pre-implantation (left picture), 3 month after implantation (right picture).

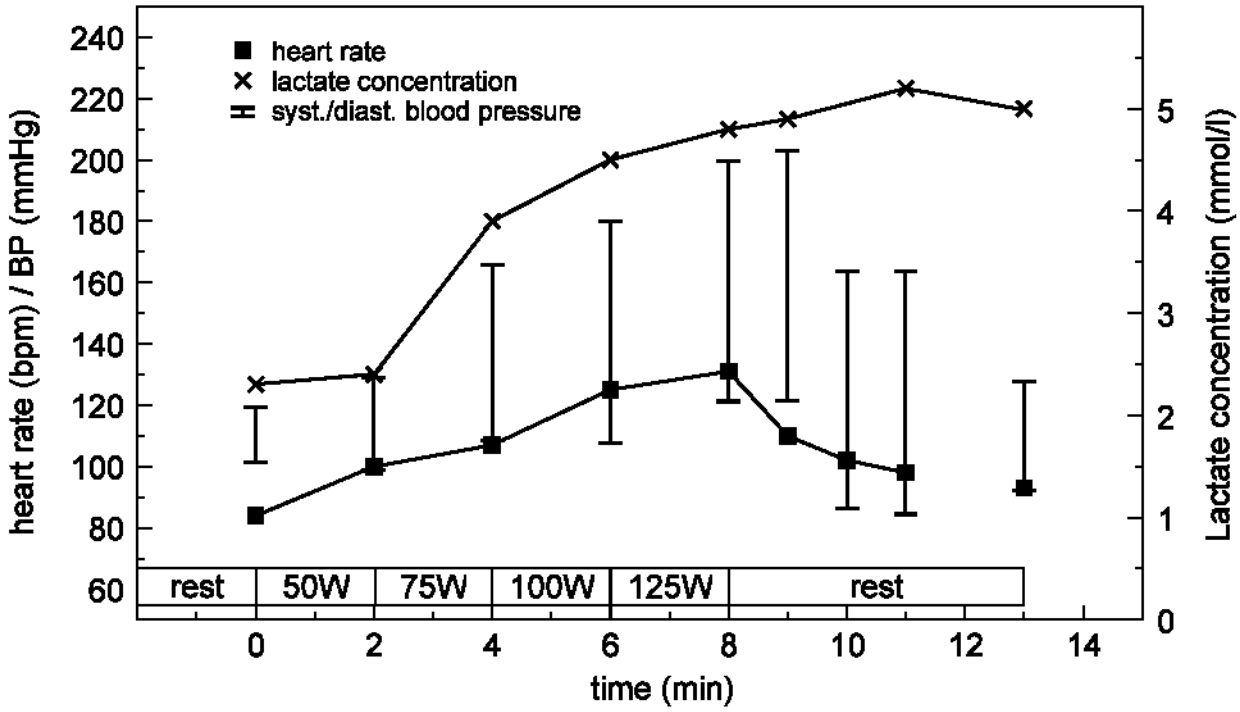

Figure 2. Ergometric bicycle test: Heart rate rose to a maximum of 131 bpm and fell to 98 bpm during the first 3 minutes after the test was stopped. Maximum blood pressure was 203/121 mmHg.

· Color word test with continual beat-to-beat measurement of heart rate and mean arterial blood pressure (with a Finapres measuring device) to show the efficacy of Closed Loop Stimulation during mental stress.

Results

The incremented ergometric bicycle tests (at 50 W, 75 W, 100 W, and 125 W for 2 min each) were stoped after 2 min at 125 W due to muscular exhaustion. Rate increase was normal, from 84 bpm at rest to 107 bpm in the range of the aerobic-anaerobic threshold for 2 min at 75 W and an additional rapid increase to a maximum of 131 bpm at the end of the test. In the course of 3 min after load was stopped, the rate returned to 98 bpm. Maximum blood pressure under load was 203/121 mmHg before the test was stopped. Overall, a low load capacity of 1.2 W per kg of body weight with adipositas per magna was determined (Figure 2).

During the polysomnography, three phases of rapid eye movement (REM) were recorded with an average increase in heart rate of 15 bpm as compared with the previous phase of deep sleep. Common occurrence of hypno- and apnea-phases with a decrease in PaO_2 (partial oxygen saturation) to a minimum of 51% with obstructive sleep-apnea syndrome (Figure 3).

The color word test increased the heart rate to 88 bpm and the MABP was increased to 130 mmHg (at rest: 81 bpm and 114 mmHg) during the first load phase, and a decrease to 82 bpm and 103 mmHg during the first rest period. During the second load period the heart rate reached 88 bpm and MABP 128 mmHg. The values fell during the subsequent rest phase to 80 bpm and 105 mmHg (Figure 4).

In the body plethysmography, a previously existing pulmonary over-inflation and a medium-degree obstruction were found. Inspiratory volume capacity (IVC) was 2.54 l; forced expiratory volume (FEV), 1.54 l; the total resistance of airway (RAW_{ToT}), 0.67 kPa/l*s.

The thoracic x-ray taken 3 months after the implantation shows non-hypertrophic heart dimensions, no congestion, no infiltrates. The pacemaker leads were in the correct position on the lateral edge of the right atrium and in the tip of the right ventricle. (see Figure 1 right)

The patient reported a subjectively perceived clear

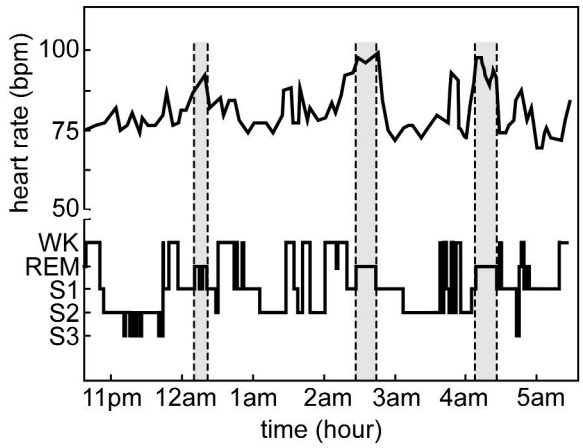

Figure 3. Polysomnography: Three REM phases (marked by dashed lines) recorded with an average increase of 15 bpm in comparison with previous deep sleep phases (REM = Rapid Eye Movement, AW = Awake, S1 - S3 = Sleep phase 1 - 3).

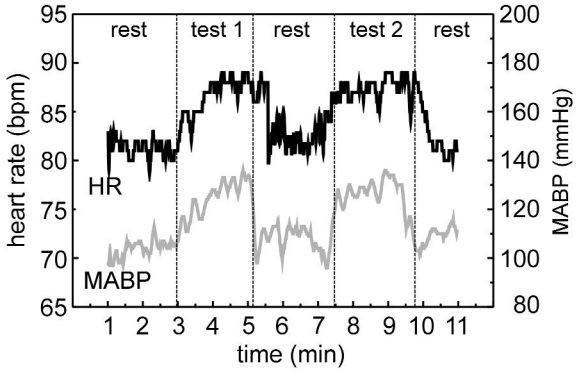

Figure 4. Color word test: During the test, heart rates were adapted according to the mental stress, during rest, the heart rates fell.

improvement of performance, improved sleeping at night, an increased ability for concentration, and overall a significantly improved quality of life.

Discussion

Limited performance capability and dyspnea on exertion are commonly correlated to limited ejection fraction with global cardiac insufficiency and must also be considered as the leading symptoms of primarily pulmonary diseases. Chronic pulmonary diseases lead to right-heart cardiac insufficiency through the pressure increase in the peripheral circulation. When multiple cardio-pulmonary diseases exist concurrently, only a subtle diagnosis can allow a causal treatment. If global cardiac insufficiency is based on a chronotropic insufficiency with lacking rate adaptation to the performance requirements of the patient with sick sinus syndrome, the implantation of rate-adaptive system of the DDDR type had only insufficient results up to now [2]. The sensor system applied could only conditionally respond to stimuli that led to a rate increase and then secondarily a blood pressure increase with chronotropic competence, because these systems were not integrated into the physiologic closed loop.

The INOS^2 CLS with its Closed Loop System is the first implant to have achieved the integration into the cardio-circulatory closed loop by analyzing cardiac contractility [3]. Our patient was implanted with such a system.

The apparent dyspnea at low levels of exertion (NYHA Class III) was of a multifactorial genesis. The COPD caused by many years of cigarette-smoking and an obstructive sleep-apnea syndrome caused by an existing metabolic dysfunction led to a load to the right-heart with beginning cor pulmonale with a pulmonary pressure gradient of 70 mmHg. The extant sick sinus syndrome with intermittent sinus arrest and interruptions lasting up to 8.7 sec and chronotropic insufficiency were the reason for a low output and a developing congestion and left-heart insufficiency. Restoring the rate- and blood pressure-adaptation through Closed Loop Stimulation (CLS) was the leading multicausal treatment concept given the absolute pacemaker indication for the patient.

The presented results impressively show that this is possible for different life and load situations with the INOS^2 CLS:

With bicycle ergometry, first a slow and constant rate increase can be determined. When the aerobic-anaerobic threshold has been surpassed (measured by the determination of lactate from the capillary blood), the rise increases sharply in order to achieve an adequate fall in rate to below 100 ppm after 3 min at the end of the exertion at 125 W [1]. The blood pressure also increases - an indication of CLS being integrated into the baroreceptor closed loop. The patient can still perform 1.2 W per kg of body weight. The high threshold rate is a result of the (still) insufficient fitness state. Overall, a clear improvement of load capability is mar-

ked by the change in NYHA Class from III to I.
Later examination in the sleep laboratory shows the clear correlation of the rate response to the phases of sleep. In the deep sleep phase, the average rate is about 15 ppm lower than during the three REM phases. Thus, a rate modulation can be observed during sleep. Because the patient did not reach the REM phase in the pre-examination, the subjective perception of sleeping better can be understood.
The color word test provided a similarly noteworthy result: during the rest phases, heart rate and blood pressure were clearly low; during mental stress, the circulatory parameters increased. This means that the Closed Loop System is the only rate-adaptive system that can also respond to mental stress with an adequate circulatory response.
The significant increase in performance and the clear improvement in the subjective state of the patient-in spite of further existing COPD and the sleep-apnea syndrome that has not been treated with continuous positive airway pressure (CPAP) respiration-can also be seen in the thoracic x-ray findings three months after the implant: signs of left- and right-heart insufficiency have decreased as reflected by the smaller outline of the heart.
According to the results collected up to now, Closed Loop Stimulation portrays an optimal therapy option for chronotropic insufficiency.

References

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