Clin. Cardiol. 30, 141–143 (2007)

Short Communication

Hemodynamic Changes During Cardiac Resynchronization Therapy

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Summary

Cardiac resynchronization therapy (CRT) is a new method for the correction of inter- and/or intraventricular conduction delays of patients with heart failure. The long-term impact of CRT on central hemodynamics is not fully characterized. We performed complete right heart catheterization studies in 31 patients receiving a CRT device pre and 6 months after implantation. Most of the patients improved in their NYHA stage, their LVEF, and in parallel showed reduced right atrial (RA) pulmonary artery (PA) and pulmonary capillary wedge (PCW) pressures and pulmonary vascular resistance both at rest and at 25 watts. In addition, we found a reduction in heart rate accompanied by an increased mean arterial pressure both at rest and at 25 watts. Accordingly, brain natriuretic peptide levels (BNP) were lowered. It was concluded that, besides other well-known effects on ventricular coordination, central hemodynamics after 6 months were improved during CRT.

Key words: cardiac resynchronization therapy, heart failure, hemodynamics

Clin. Cardiol. 2007; 30: 141–143.

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Received: March 20, 2006
Accepted with revision: September 12, 2006

Published online in Wiley InterScience
(www.interscience.wiley.com).
DOI:10.1002/clc.11

Introduction

An intraventricular conduction delay is present in many patients with heart failure and was identified as an independent risk factor for mortality.[1] It has been recently shown that correcting this condition by biventricular pacing cardiac resynchronization therapy (CRT) could improve NYHA stage, life quality, oxygen uptake, cardiac diameters, ejection fraction, and even prognosis.[2–4] Central hemodynamics also were shown to improve in acute testings,[5] but no data have been published till now on their long-term course using repeated right heart catheterization.

Methods

We performed complete right heart catheterization studies in 31 patients receiving a CRT device pre and 6 months after implantation. Patients had been on stable heart failure therapy for at least three months preimplantation. Arterial pressures were directly measured by additional cannulation of radial arteries. Mean age of the patients was 50 ± 8 years, mean NYHA stage was 3.3 ± 0.4, and mean LVEF was $25\% \pm 6\%$. There were 77% men in the study population, and 52% had coronary artery disease as the underlying etiology of heart failure. Pacemaker implantations with coronary sinus leads were performed with standard techniques via left or right cephalic or subclavian veins. Leads used were EASY-TRAK 4513 (n = 21, Guidant, U.S.A.) and ATTAIN 4193 (n = 10, Medtronic, U.S.A), and pulse generators used were CONTAK TR (Guidant) and INSYNC III (Medtronic). Early and routine follow-up investigations were performed, which included impedance, sensing, threshold measurements, echocardiographic, hemodynamic and clinical data. Right heart catheterization results were obtained at rest and during exercise at a standard load of 25 watts during 5 min. Differences in the results were checked for significance by means of Student's t-test for matched pairs. All data were expressed as mean ± standard deviation. For analysis, SPSS for Windows 6.1 was used.

Results

Preoperative data and data at reevaluation 6 months later are shown in Table 1. Biventricular stimulation (CRT) shortened QRS width by a mean of 12%. Medical therapy was slightly modified in terms of a small reduction in diuretic therapy and a small increase in β-blocker dosage. ACE inhibitor dosage overall was unchanged. After 6 months, patients improved in their mean NYHA stage by more than one class. From the cohort, 26/31 patients (84%) could be classified as responders to CRT defined as an improvement of at least one NYHA class. The clinical improvement was correlated with increased LVEF and reduced filling pressures of the right and left ventricles (right atrial (RA) and pulmonary capillary wedge (PCW) pressures, both at rest and at 25 watts). Also, pulmonary artery (PA) pressures and pulmonary vascular resistance were lower than at baseline (Table 1). Brain natriuretic peptide (BNP) levels were shown to be reduced. Another important hallmark of the improvement associated with CRT was a reduced heart rate accompanied by an increased mean arterial pressure both at rest and at 25 watts (increased pulse pressure).

Discussion

In severe heart failure, CRT improves the clinical status, echocardiographic values, and data derived from right heart catheterization studies both at rest and during 25 watts workload after 6 months of active stimulation. The major improvement of resynchronization seems to be due to a reduction of neurohumoral activation. This was reflected by a lower heart rate at rest and at 25 watts and lower levels of serum brain natriuretic peptide. This fits well with the findings of Hamdan *et al*.[6] of an acute reduction in sympathic nerve activity by biventricular pacing. The second benefit seems to be a higher mean arterial pressure both at rest and, even more pronounced, at exertion, accompanied by reduced filling pressures. These beneficial changes led to an increase in cardiac stroke work. A very attractive side effect was the lowering of pulmonary arterial resistance (PVR) under CRT. This raises the possibility of preoperative conditioning when heart transplantation is not avoidable, because it is well known that high PVR was negatively correlated to outcome after HTx. As to the mechanisms, this was in agreement with the results of Nelson *et al*., which shows that CRT increases LV dp/dt without an increase

TABLE 1 Patients characteristics at entry and at follow-up after 6 months

	Baseline	Month 6	P
ACE-inhibitor (mg/day)	19 ± 18	22 ± 17	Ns
β-blocker dosage (mg/day)	32 ± 24	47 ± 46	0.03
Furosemid dosage (mg/day)	77 ± 49	50 ± 29	<0.01
NYHA stage	3.3 ± 0.4	2.0 ± 0.6	<0.01
QRS-duration (ms)	183 ± 29	164 ± 20	<0.01
LVEF (%)	25 ± 6	35 ± 12	<0.01
LVEDD (cm)	6.7 ± 0.9	6.4 ± 0.9	<0.01
FS (%)	18 ± 4	25 ± 8	<0.01
Mitral regurg	1.6 ± 0.9	0.9 ± 0.9	<0.01
Tricuspid regurg	0.8 ± 0.9	0.3 ± 0.7	<0.01
Cardio thoracic ratio	0.58 ± 0.06	0.55 ± 0.07	<0.01
Sodium (mmol/L)	135 ± 5	136 ± 3	Ns
Creatinine (mg/dL)	1.2 ± 0.4	1.3 ± 0.6	Ns
Brain natriuretic peptide (pg/mL)	664 ± 517	366 ± 337	<0.01
Heart rate (/min)	73 ± 17	62 ± 9	<0.01
Heart rate 25 watt (/min)	90 ± 19	77 ± 13	<0.01
MAP (mmHg)	69 ± 11	72 ± 10	<0.01
MAP 25 watt (mmHg)	73 ± 12	84 ± 13	<0.01
RAP (mmHg)	6 ± 6	3.5 ± 3	<0.01
RAP 25 watt (mmHg)	12 ± 4	11 ± 7	Ns
PAM (mmHg)	30 ± 13	20 ± 10	<0.01
PAM 25 watt (mmHg)	41 ± 12	36 ± 12	<0.01
PCP rest (mmHg)	18 ± 9	10 ± 7	<0.01
PCP 25 watt (mmHg)	28 ± 9	23 ± 8	<0.01
Pulmonary Vascular resistance (dyn)	219 ± 147	168 ± 131	<0.01
LVSWI (pm)	22 ± 8	34 ± 9	<0.01
LVSWI 25 watt (pm)	24 ± 8	35 ± 12	<0.01
aVDO2 (Vol%)	6.3 ± 1.2	5.4 ± 1.2	<0.01
aVDO2 (Vol%) 25 watt	11 ± 2	10.5 ± 2	Ns
CI L/min*kgKG	2.2 ± 0.5	2.5 ± 0.5	0.02
CI 25 Watt L/min*kgKG	3.2 ± 0.6	3.2 ± 0.7	Ns

in myocardial oxygen consumption.[7] This translates into beneficial clinical effects reported from large randomized studies. However, we cannot exclude a small bias in our study due to a somewhat higher dosage of β-blocking agents at 6 months (Table 1). This difference is relatively small and may be due to a hitherto undescribed improved tolerance of β-blockers during CRT pacing.

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