Abstract – In heart failure, the heart does not pump blood as well as it should and fluid builds up in the lungs. The symptoms of heart failure include difficulty breathing, decreased ability to exercise, and leg swelling. Although many drugs help patients with heart failure, there is no cure. In patients with heart failure, conduction of electrical impulses through the heart is often abnormal. This abnormal conduction, in turn, can lead to uncoordinated contraction of the ventricles, the large pumping chambers of the heart. Cardiac resynchronization is a newer heart failure treatment that uses a special type of pacemaker to synchronize the contraction of the ventricles. Cardiac resynchronization improves quality of life and exercise ability, but its effect on survival has been less clear.

Keywords: cardiac resynchronization therapy, heart failure, pacemaker

1. Introduction

Cardiac resynchronization therapy (CRT) is a proven treatment for selected patients with heart failure-induced conduction disturbances and ventricular dyssynchrony. When used in combination with stable, optimal medical therapy, CRT is designed to reduce symptoms and improve cardiac function by restoring the mechanical sequence of ventricular activation and contraction.

2. Results

In 20%-30% of congestive heart failure patients an additional dysfunction of the intraventricular spread of stimulus is observable (broad QRS-complex > 150 ms). This asynchronisation leads to an impairment of systolic function.

Goal of the cardiac resynchronization therapy (CRT) is the stabilisation of the contraction due to a synchronization of the right and left ventricular excitation. The optimization of the stimulation interval between atrium and ventricle – AV-delay – also improves diastolic function of the heart and increases cardiac function up to 5%-10% in patients with CRT-pacemakers and thus improves patients’ lives.

Many patients with advanced systolic heart failure exhibit significant intra- or interventricular conduction delays (IVCD) that disturb the synchronous beating of the ventricles so that they pump less efficiently. This delayed ventricular activation and contraction is referred to as ventricular dyssynchrony and is often seen as a wide QRS complex with a left bundle branch block morphology on ECG.

Ventricular dyssynchrony has been shown to have a number of deleterious effects on cardiac function, including reduced diastolic filling time, weakened contractility, protracted mitral regurgitation, and post-systolic regional contraction—that together result in diminished stroke volume.

A number of studies have shown a wide QRS to be associated with a poor prognosis. One-year follow-up data from the Italian Network on Congestive Heart Failure (IN-CHF) registry found that the concurrent presence of left bundle branch block and atrial fibrillation with heart failure was associated with a significant increase in mortality, and that this synergistic effect remained significant even after adjusting for clinical variables usually associated with advanced heart failure. In a study by Iuliano of 669 NYHA class II-IV heart failure patients, a prolonged QRS was associated with increased mortality (49.3% vs. 34.0%) and sudden death (24.8% vs. 17.4%), while LBBB was associated with worse survival, but not sudden death. Finally, in a substudy analysis from the Vesnarinone Study (VEST), patients with NYHA class II-IV heart failure who had a wider QRS (>200 ms) had a five-times greater mortality risk than those with the narrowest QRS duration (<90 ms).

Cardiac Resynchronization Therapy provides atrial-synchronized, biventricular pacing using standard pacing technology combined with a special third lead that is implanted via the coronary sinus and positioned in a cardiac vein to sense and/or pace the left ventricle. Following a sensed atrial contraction or atrial-paced event, both ventricles are stimulated to synchronize their contraction. The
resulting ventricular resynchronization reduces mitral regurgitation and optimizes left ventricular filling, thereby improving cardiac function\textsuperscript{8-11}.

Several studies now document the remarkable benefits conferred by CRT on appropriately selected patients with heart failure.

CRT uses a specialized pacemaker to re-coordinate the action of the right and left ventricles in patients with heart failure.

In approximately 30\% of patients with heart failure, an abnormality in the heart's electrical conducting system (called an "intraventricular conduction delay") causes the two ventricles to beat in an asynchronous fashion. That is, instead of beating simultaneously, the two ventricles beat slightly out of phase. This asynchrony greatly reduces the efficiency of the ventricles in patients with heart failure, whose hearts are already damaged.

CRT re-coordinates the beating of the two ventricles by pacing both ventricles simultaneously. This differs from typical pacemakers, which pace only the right ventricle. Early studies with CRT demonstrated its ability to improve the symptoms, the exercise capacity, and the feeling of well-being of many patients with moderate to severe heart failure. Additional studies showed that CRT can improve both the anatomy and function of the heart - tending to reduce the size of the dilated left ventricle, and improving the energy usage of the heart.

**Fig. 1** Third lead that is implanted via the coronary sinus and positioned in a cardiac vein to sense and/or pace the left ventricle

Contraindications of CRT are: asynchronous pacing is contraindicated in the presence (or likelihood) of competitive or intrinsic rhythms. Unipolar pacing is contraindicated in patients with an implanted defibrillator or cardioverter-defibrillator (ICD) because it may cause unwanted delivery or inhibition of defibrillator or ICD therapy. CRT-ICD Devices are contraindicated for patients whose ventricular tachyarrhythmias may have transient or reversible causes and for patients with incessant VT or VF. CRT Devices are contraindicated for Dual chamber atrial pacing in patients with chronic refractory atrial tachyarrhythmias. CRT are contraindicated for patients with coronary venous vasculature that is inadequate for lead placement, as indicated by venogram.

Potential device complications include, but are not limited to, rejection phenomena, erosion through the skin, muscle or nerve stimulation, oversensing, failure to detect and/or terminate tachyarrhythmia episodes, acceleration of ventricular tachycardia, and surgical complications such as hematoma, infection, inflammation, and thrombosis.

In the fall of 2003, the COMPANION trial showed that CRT can reduce the need for hospitalization, and may improve survival in patients with heart failure. In the COMPANION trial, over 1600 patients with significant heart failure (including recent prior hospitalizations for heart failure, and intraventricular conduction delays, were randomized to to receive optimal drug therapy, or optimal drug therapy plus CRT. (Half the patients receiving CRT got a CRT device that also acts as an implantable defibrillator; the other half got CRT pacing alone).

Results from COMPANION confirm that patients receiving either kind of CRT device had more than a 20\% reduction in the composite endpoint of the study (i.e., total hospitalizations and death from any cause.) Furthermore, patients who received the CRT-plus-defibrillator showed a 36\% reduction in mortality alone. Those who received CRT without the defibrillator showed a trend toward a 24\% reduction in mortality alone, though the trend did not quite reach statistical significance.

**Fig. 2** Coronary venogram and fluoroscopic view of the three leads used for CRT
Cardiac Resynchronization Therapy provides atrial-synchronized, biventricular pacing using standard pacing technology combined with a special third lead that is implanted via the coronary sinus and positioned in a cardiac vein to sense and/or pace the left ventricle. Following a sensed atrial contraction or atrial-paced event, both ventricles are stimulated to synchronize their contraction. The resulting ventricular resynchronization reduces mitral regurgitation and optimizes left ventricular filling, thereby improving cardiac function.

The implant procedure of a CRT device is much the same as that for a pacemaker or implantable defibrillator, although additional time is required to place the left ventricular lead in a suitable cardiac vein via the coronary sinus. It is important to note that coronary venous anatomy varies significantly between patients, and in a small percentage of cases, it may not be possible to place the left ventricular lead transvenously. In such situations, some centers are opting for an epicardial approach if the transvenous approach is unsuccessful.

Randomized controlled trials, 12, 13 which have now included over 2,500 patients, have shown that about 70% of patients with NYHA class III/IV heart failure, a QRS duration ≥ 130 ms, a left ventricular ejection fraction ≤ 35%, and a left ventricular end-diastolic diameter ≥ 55 mm respond favorably to CRT. Additional studies, including a large, multicenter trial to assess the potential of echo-based measures of dyssynchrony, are currently underway to help better identify those patients most likely to respond to CRT.

### Indications for CRT:
- Symptomatic despite stable, optimal medical therapy
- NYHA class III-IV (moderate to severe) heart failure
- Ventricular dyssynchrony demonstrated by QRS duration ≥ 130 ms
- Left ventricular ejection fraction ≤ 35%

### 3. Discussions

A number of randomized, controlled clinical studies have demonstrated that CRT has a number of positive clinical effects, including: reduction in left ventricular end-diastolic volume and diameter, improvement in cardiac function and structure, improvement in quality of life and functional capacity, improvement in exercise capacity, reduction in heart failure hospitalization, reduction in mortality (CRT-D) from progressive heart failure.

Recent large prospective, randomized clinical trials confirm the efficacy of cardiac resynchronization therapy (CRT) in indicated heart failure patients.

The implant procedure of a CRT device is much the same as that for a pacemaker or implantable defibrillator, although additional time is required to place the left ventricular lead in a suitable cardiac vein via the coronary sinus. It is important to note that coronary venous anatomy varies significantly between patients, and in a small percentage of cases, it may not be possible to place the left ventricular lead transvenously. In such situations, some centers are opting for an epicardial approach if the transvenous approach is unsuccessful.

Randomized controlled trials, 12, 13 which have now included over 2,500 patients, have shown that about 70% of patients with NYHA class III/IV heart failure, a QRS duration ≥ 130 ms, a left ventricular ejection fraction ≤ 35%, and a left ventricular end-diastolic diameter ≥ 55 mm respond favorably to CRT. Additional studies, including a large, multicenter trial to assess the potential of echo-based measures of dyssynchrony, are currently underway to help better identify those patients most likely to respond to CRT.

### Indications for CRT:
- Symptomatic despite stable, optimal medical therapy
- NYHA class III-IV (moderate to severe) heart failure
- Ventricular dyssynchrony demonstrated by QRS duration ≥ 130 ms
- Left ventricular ejection fraction ≤ 35%

### 3. Discussions

A number of randomized, controlled clinical studies have demonstrated that CRT has a number of positive clinical effects, including: reduction in left ventricular end-diastolic volume and diameter, improvement in cardiac function and structure, improvement in quality of life and functional capacity, improvement in exercise capacity, reduction in heart failure hospitalization, reduction in mortality (CRT-D) from progressive heart failure.

Recent large prospective, randomized clinical trials confirm the efficacy of cardiac resynchronization therapy (CRT) in indicated heart failure patients.

### 4. References

Stunning results in heart failure with cardiac resynchronization therapy


