

Skeletal Muscle Cardiocirculatory-Assist by Demand Dynamic Cardiomyoplasty: 5-Year Results

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Abstract

Dynamic Cardiomyoplasty provides an active girdle effect by wrapping the left latissimus dorsi muscle around the heart. This technique has almost been abandoned in the last 5 years, because continuous electrical stimulation damages the muscle wrap, compromising long-term results. An activity-rest stimulation protocol, which avoids complete transformation of the skeletal muscle, thus maintaining muscular properties overtime, has recently been proposed. This protocol has provided promising results in humans, in terms of NYHA class, EF and survival improvement. Despite recent exclusion of the standard technique from the ACC/AHA guidelines for management of patients with heart failure, debate on this unique kind of cardiocirculatory bio-assistance has been re-opened. Demand dynamic cardiomyoplasty, besides being effective, could also be cost saving by avoiding extracorporeal circulation, immunosuppression therapy and the expensive follow-up of heart transplant patients.

Key words: circulatory assist, demand dynamic cardiomyoplasty, heart failure.

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In the 80s dynamic cardiomyoplasty was thought a valid alternative to heart transplant for treatment of heart failure [7, 12, 13, 21, 36, 44]. Nevertheless, in the last ten years there has been a decline in its application due to poor long-term results, which are secondary to latissimus dorsi (LD) degeneration [22-26]. To avoid excessive muscular degeneration and maintain long-term partial transformation of the LD wrap, fewer impulses per day than in standard clinical stimulation should be delivered. The LD wrap could be provided with daily periods of rest by Demand Stimulation based on a heart rate cut-off [2].

To our opinion, the encouraging preliminary results in sheep and in humans [2-3, 9, 41, 42] re-open debate on the role of dynamic cardiomyoplasty in the treatment of heart failure, despite recent exclusion of this technique from the ACC/AHA guidelines [3].

Surgical Procedures

Dynamic CardioMyoPlasty (DCMP), in the original Broussais Hospital procedure created by Carpentier et al [8], includes the mobilization of the left LD muscle with its intact thoracodorsal neurovascular pedicle, its

transposition into the chest and the creation, by wrapping the muscle around the heart, of an active girdle effect. The LD, after a two-week period during which cardiac assistance is not provided, is electrically stimulated by a cardiomyostimulator located in the abdomen to contract simultaneously to the heart. The muscle, which contains mixed fibres, is converted into an almost pure type 1, highly fatigue-resistant muscle, by means of chronic electrical stimulation and gradual increase in impulse duration and frequency [13].

Ideal candidates for this procedure are considered those patients with ischemic or dilative cardiomyopathy and moderate-severe impairment of left ventricular function (intermittent NYHA class III/IV, but class III at the time of intervention), that are unstable or with a tendency towards deterioration despite maximal medical therapy. Mitral or tricuspid regurgitation should not exceed grade II, serum creatinine should be < 2.5 mg/dl, and no signs of organ failure should be present [7, 13, 21].

It has been established that a combined implantation of DCMP cardiomyostimulator and cardioverter defi-

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brillator, further improves survival in heart failure patients with ventricular arrhythmias [17, 18].

Worldwide Results of Dynamic Cardiomyoplasty

With the described stimulation protocol, the fast, powerful (but early fatiguing) LD is transformed by continuous stimulation into a slow-contracting muscle, which is fatigue-resistant at moderate contraction forces. Nevertheless, the contraction-relaxation cycle of a fully conditioned LD may last longer than the cardiac cycle itself, causing significant degeneration of the LD wrap [22].

The two principal hypotheses on the mechanism of cardiac assistance by DCMP are limited heart dilatation and enhanced systolic contraction [2, 3, 9, 39]. A significant improvement in NYHA class has been reported worldwide, usually passing from class III or higher to class II or lower [3, 7, 16, 20, 26, 46]. On the other hand, enhancement of systolic contraction is only suggested by minor improvements in stroke volume [4] and by low-to-moderate increase in ejection fraction, both of them being limited to early follow-up periods [5, 6, 29, 40, 44, 47, 48]. Early and late mortality rates range from 0 to 27% and from 11 to 38.7%, respectively. Maximum survival rate was 70% at 4 years [27, 28, 31, 32, 34, 38, 39].

Pathological and morphological studies [25] suggest that degeneration of the muscle is probably caused by surgical dissection and exacerbated by chronic stimulation. Moreover, the initial 2-week delay in the stimulation of the LD after cardiomyoplasty seems to contribute to muscle atrophy and loss of function [43]. To enhance power of the LD wrap, the “vascular delay”, a 10-day ischemic preconditioning period prior to DCMP intervention, has also been suggested in order. In animal models, the “vascular delay” caused an improvement not only in muscle performance, but also in muscular perfusion [1, 19, 43, 45].

Demand Dynamic Cardiomyoplasty

Demand stimulation of the LD wrap [41] was introduced to homogenise patient response and to avoid complete LD wrap transformation, which was caused by the continuous stimulation protocol of the FDA phase II trial in use by the American Cardiomyoplasty Group [22].

It is well established that a muscle fully transformed by continuous stimulation displays significant loss in power, generally attributed to fiber-type change or loss of type 2 myofibers (fast contracting myofibers). Insertion of rest periods during chronic electrical conditioning preserves myofiber cross-sectional area and produces fatigue-resistant fiber distributions. Thus, a more powerful, fatigue-resistant muscle is obtained. The improved performance of such a LD is due to maintenance of an intermediate level of transformation of the LD wrap, thanks to the demand regimen. After a healing period of 10-14 day, LD stimulation was done with a single impulse at a 1:3 synchronization ratio. An im-

pulse was added every week at a 23 msec pulse interval (43 Hz) for a final burst of four impulses with a cardiac amplitude < 5 Volts and pulse width of 1.5 msec. After 6-12 months of this “light” daily stimulation, the patients were submitted to the “demand regime” allowing the LD wrap periods of rest throughout the day.

To provide the LD wrap with daily periods of rest, 24-hour Holter study was previously performed to determine the average heart rate during sleeping hours. The pacing parameters of the cardiomyostimulator (Transform, Model 4710, Medtronic, Inc., Minneapolis, MN, USA) were programmed at a rate of 70-80 bpm, with minimum pulse amplitude (< 1 Volts) and pulse width (< 0.05 msec). Muscle output was programmed to “Sense” thus occurring only with sensed cardiac events and not with paced events. In this way, the lower rate was set just above average nocturnal heart rate and the cardiomyostimulator worked in resting hours at an energy level well below that required for capturing the heart. During these pacing episodes, muscle output was inhibited. The result was that muscle stimulation was inhibited during resting hours and occurred at the programmed synchronization ratio during active hours, providing an activity-rest stimulation regimen.

Monitoring of the contractile characteristics of the LD wrap, such as speed of contraction and relaxation, were done as described elsewhere [10]. In brief, using a standard polygraph (for example the MegaCart or Mingophon, Siemens Elema, Solna, Sweden) electrocardiogram, heart sounds and pressure changes due to LD wrap contraction and relaxation are simultaneously recorded. The LD motion is monitored by placing the pressure transducer, which was used to monitor cardiac apical motion, at the location of the rib window through which the LD enters in the thoracic cavity. The dynamic characteristics of the LD wrap can be determined from the LD response to stimuli delivered at increasing frequency up to tetanic fusion frequency

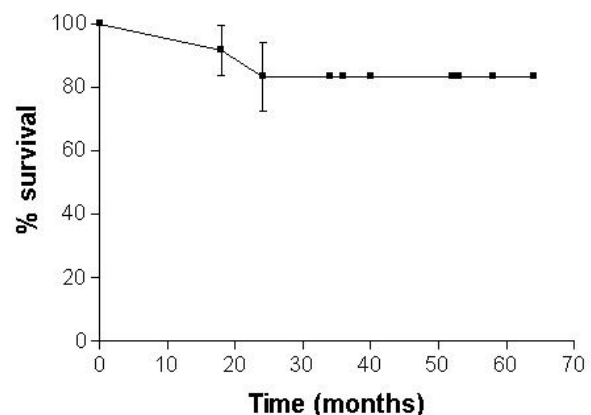


Figure 1. Five-year actuarial survival of the patients in the Italian Trial on Demand Dynamic Cardiomyoplasty (ITDDC).

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(TFF). In this way, a smooth contraction curve can be plotted: the faster the fibres, the higher the TFF [10]. This method is also used for monitoring cardiac/LD contraction synchronization [3].

5-Year Results of the Italian Trial of Demand Dynamic Cardiomyoplasty

Twelve patients (11/1 = M/F, mean age 58.2 ± 5.8 years, sinus rhythm/atrial fibrillation = 11/1) with dilated cardiomyopathy, were submitted in the years between 1993 and 1996 to DCMP and at different intervals to Demand protocol. The mean duration of follow-up was 40.2 ± 13.8 months (range 18-64 months).

Post procedural NYHA class was significantly lower when compared with pre-operative data: 1.67 ± 0.77 versus 3.17 ± 0.38 ($p = 0.0001$). The number of hospitalizations for congestive heart failure significantly decreased, from 3.2 ± 0.4 to 1.1 ± 1.08 per year ($p = 0.0001$).

The mean EF at follow-up was significantly higher compared to pre-operative values ($32.0 \pm 7.0\%$ versus $22.6 \pm 4.38\%$, $p < 0.001$), whereas mean end-diastolic volume did not change significantly during the follow-up (114 ± 41.1 versus 104 ± 9.9 ml/m², $p = 0.67$).

Swan-Ganz catheterisation demonstrated a non-significant decrease in the capillary wedge pressure (12.2 ± 6.11 versus 11.7 ± 7.19 mmHg, $p = 0.83$).

Mechanographic interrogation showed a significant increase in TFF at follow-up (33 ± 7.86 versus 15.8 ± 11.1 Hz, $p = 0.0001$).

Perioperative mortality was zero. During follow-up, one patient died of hepatic cancer at 36 months and another one died of massive pulmonary embolism at 18 months from operation. Both were NYHA class I one months prior to death. One patient received a bi-ventricular pacing- defibrillator device for the development of left bundle branch block and ventricular arrhythmias, without interfering with the myostimulator. Two patients, in whom continuous stimulation had been performed for several months (107 and 57 months, respectively), were switched to the heart transplantation program. In one case because of deterioration of clinical conditions (NYHA class III, co-treated with biventricular pacing) and in the other due to myostimulator dysfunction (previously in NYHA class II). The actuarial 5-year survival rate is 83.3% (Figure 1).

Perspectives

Despite the great technological advances in Cardiology, the treatment of end-stage heart failure remains challenging. Even though heart transplantation offers excellent functional results, donors are still scarce and chronic rejection limit survival to 38% at 12 years [35]. Moreover, cardiac transplantation is extremely costly both in its performance and follow-up. A simpler, more economic and widely available alternative should therefore be considered: demand dynamic cardiomyoplasty could be the

answer, especially in countries that cannot devote great amounts of money to heart failure programs.

In fact, demand dynamic cardiomyoplasty, by not requiring extracorporeal circulation, immunosuppression therapy, repeated endomyocardial biopsies on follow-up and anticoagulation therapy, can greatly reduce costs. Moreover, there is no need for a compatible donor and is therefore available to everyone who needs it. A dedicated cardiomyostimulator, which combines work-rest regimens with night/day activity levels, will soon be available. Demand stimulation, together with the vascular delay approach, may be the keys for successful long-term LD stimulation [16, 30, 33].

In conclusion, despite the exclusion of classic DCMP from the recent ACC/AHA guidelines for the evaluation and management of chronic heart failure [23], reconsideration of the role of Demand Dynamic Cardiomyoplasty, in light of the results described above, is not only reasonable but necessary.

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