

Dynamic Cardiomyoplasty and Aortomyoplasty: the Buenos Aires Experience

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Abstract

The aim of the present study is to evaluate results obtained after applying dynamic cardiomyoplasty or Aortomyoplasty to patients with dilated cardiomyopathy and severe ventricular dysfunction (Functional Class III-IV, New York Heart Association).

A dynamic cardiomyoplasty procedure was performed in 15 patients with a mean age of 59.2 ± 6.4 years. Despite the medical treatment with inhibitors of the converted enzyme of vasodilators, these patients required 2.2 ± 0.7 hospitalizations/patient/year owing to congestive heart failure in the year before dynamic cardiomyoplasty was applied. In 8 patients the etiology of the cardiomyopathy was idiopathic, ischemic-necrotic in 6 and Chagas' disease in the other.

Hemodynamic studies were done preoperatively in all patients and every six months postoperatively.

Twelve patients had a follow-up for two years. The following values related to two-years evaluation improved significantly in comparison with baseline: Functional Class (1.7 ± 0.6 versus 3.06 ± 0.2); radionuclide left ventricular ejection fraction ($29.7\% \pm 5$ versus $23.6\% \pm 3$); fractional shortening ($20.6\% \pm 5$ versus $15.6\% \pm 4$). Walking test values increased from $332 \text{ meters} \pm 127$ to $421 \text{ meters} \pm 102$. Left ventricular diastolic diameter remained unchanged ($72.7 \text{ mm} \pm 7$ versus $72.3 \text{ mm} \pm 8$).

Improvement was observed in functional capacity and left ventricle systolic function parameters two years after cardiomyoplasty.

Aortomyoplasty: six patients were included with mean age of 52 years and a Functional Class III-IV. One patient died two months later (ventricular arrhythmia) before completing the stimulation protocol. The other 5 patients improve the Functional Class with a value of I-II at 12 months postoperative average.

Key words: aortomyoplasty, cardiomyoplasty, latissimus dorsi muscle, skeletal muscle, cardiomyopathy.

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Congestive heart failure (CHF) is an important cause of morbidity and death. Although heart transplants are a good alternative for patients with advanced CHF, they can only be applied to a reduced number of patients. Natural limitations, lack of donors or clinical and socioeconomic contraindications restrict their use. For CHF patients and even for those who have not reached the clinical stage of a transplant, dynamic cardiomyoplasty (DC) offers an alternative to improve functional class and life expectancy. Since its introduction in 1985 by Carpentier and Chachques [3], this technique has undergone different stages with the aim of placing its role in the clinical practice [1, 4, 5, 7, 9, 10, 11, 12, 14, 21, 24].

The purpose of the present report is to evaluate immediate and long-term results of the DC in Argentina, concerning a group of patients with dilated cardiomyopathy.

Materials and Methods

Population study

The study included idiopathic or ischemic-necrotic dilated cardiomyopathy patients with a left ventricle ejection fraction of less than 30% and a functional class (FC) III - IV according to the New York Heart Association (NYHA). These patients were refractory to habitual pharmacological treatments. Candidates for heart transplant or other specific surgical treatments

were excluded. Fifteen patients (11 males and 4 females) were operated using a DC procedure. They ranged from 46 to 74 years old and their average age was 59.2 ± 6.4 years. Although they were treated with inhibitors of the converted enzyme or vasodilators, these patients required 2.2 ± 0.7 hospitalizations per patient per year owing to CHF decompensation in the year before DC was applied.

The etiology of dilated cardiomyopathy was idiopathic in 8 patients, ischemic-necrotic in 6 and Chagas' disease in the other. The presence of myocardial viability was discarded in the second group of patients by means of radioisotopic studies.

Chest x-rays showed an average cardiothoracic ratio of 0.59 ± 0.04 and signs of venocapillary high blood pressure in 15 patients. Preoperative echocardiographic studies revealed a severe dilatation of the left ventricle. The average values were: left ventricle diastolic diameter (LVDD) $72.7 \text{ mm} \pm 3$; left atrial diameter (LAD) $55.5 \text{ mm} \pm 10$; fractional shortening (FS) $15.6\% \pm 4$.

The left ventricular ejection fraction (LVEF) measured by means of radioisotopic ventriculography with Technetium 99 was $23.6\% \pm 3$, whereas the left ventricular end-diastolic pressure (LVEDP) evaluated during cardiac catheterization was $23.2 \text{ mm Hg} \pm 8$. The oxygen consumption was $13.3 \text{ ml/kg/min} \pm 3$.

According to the NYHA classification, 14 of the patients were in FC III and 1 in FC IV (average 3.06 ± 0.2). To get an objective FC, patients were subjected to a 6-minute walking test, developing an average distance of $332 \text{ meters} \pm 127$. Three patients had atrial fibrillation with controlled ventricular frequency, the others were in sinus rhythm.

One patient had a previous revascularization surgery and another one had moderate mitral regurgitation requiring concomitant mitral annuloplasty.

Latissimus Dorsi muscle stimulation

A two-chamber programmable pacemaker (Elite 7074, Medtronic) was used in 5 patients, the SP 1005 Medtronic cardiomyostimulator in 6 patients and a Transform 4710 Medtronic cardiomyostimulator in the other 4 patients.

Stimulation began after the first two weeks, in order to favour muscle adhesions to the epicardium and the development of collateral circulation. Stimulation was then started on a progressive and regular basis. Thus, definite programming was set around the tenth week. The following technical aspects were taken into account: 1) the pulse train was set in the final period of QRS so that the stimulus could coincide with the closing of the mitral valve checked by echocardiography; 2) the maximum amplitude reached did not surpass the total stimulation threshold measured during surgery. The latter is defined as the minimum voltage that enables the

total contraction of the muscle; 3) programmed stimulation remained at a 1:2 sequence in relation to heart rate.

Follow-up protocol

Ventricular function was measured in all the patients before surgery and every 6 months postoperatively by means of echocardiography and radioisotopic ventriculography (Technetium 99) [22, 23]. FC was monitored through a 6-minute walking test and oxygen consumption.

The long-term study excluded patients with a postoperative period of less than two years. Twelve patients were included in this evaluation.

Results and Discussion

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Immediate postoperative period

Only one death (6.6%) occurred in the hospital, twenty-four hours postoperatively because of ventricular arrhythmia. All the patients required pharmacological support with inotropics, although only three of them remained with this medication for more than 48 hours. Four patients showed low cardiac output syndrome and 2 of them renal failure. No patient required mechanical circulatory support.

The average postoperative bleeding was $352 \text{ ml} \pm 123$ and there was no need to reoperate on. There were no respiratory complications as a consequence of intrathoracic muscular mobilization. The period of mechanical respiratory support was $12.5 \text{ hours} \pm 8.3$.

There were supraventricular tachyarrhythmias in 4 patients and ventricular tachyarrhythmias in other 3. A patient suffered from a temporary ischemic stroke 12 days after surgery was performed, but there were no definitive after-effects. In three cases, there was seroma in the injury of the thoracotomy but it was stopped by means of compression. In one patient, there was an infection in this incision, which was controlled through local treatment. At present, patients are subjected to an early compression of the thorax in order to avoid seroma.

The patients remained in the intensive care unit during $4.7 \text{ days} \pm 1.9$. The total hospitalization time was $21.7 \text{ days} \pm 11$.

Long-term evolution

From the 14 patients discharged from hospital, 1 died two months later before completing the stimulation protocol. This was due to CHF progression. The other 13 completed the stimulation protocol; 12 of them surpassed the absolute postoperative period of two years, with an average of 31.3 months per patient.

This long-term evolution study will include the 12 patients who had a postoperative period of more than

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Table 1. Summary of the results (two years) (n. 12 patients).

	Preop	Post-op One year	Post-op Two Years	p Value
FC (NYHA)	3.06 ± 0.2	1.8 ± 0.6	1.7 ± 0.6	< 0.0001
Hosp/y/p	2.2 ± 0.7	----	0.4 ± 0.5	= 0.002
WALKING TEST (m)	332 ± 127	406 ± 119	421 ± 102	= 0.019
VO ₂ (ml/kg/m)	13.3 ± 3	----	14 ± 3	NS
LVEF (%)	23.6 ± 3	28 ± 2	29.7 ± 5	= 0.001
LVDD (mm)	72.7 ± 3	73.6 ± 7	72.3 ± 8	NS
FS (%)	15.6 ± 4	18 ± 4	20.6 ± 5	= 0.003
LAD (mm)	55.5 ± 10	55.6 ± 5	53.2 ± 10	NS*

NS*: P = 0.07 NS trend.

FC: functional class (New York Heart Association); Hosp/ylp: Hospitalizations/ year/patient; VO₂: oxygen consumption; LVEF: left ventricular ejection fraction; LVDD: left ventricular diastolic diameter; NS: not significative; FS: fractional shortening; LAD: left atrial diameter.

two years. After one year follow-up, these patients had an FC of 1.8 ± 0.6, whereas after two years follow-up their FC was of 1.7 ± 0.6. Only small doses of specific medication were required in the postoperative period.

One year before surgery, this group had had an average of 2.2 ± 0.7 hospitalizations per patient, whereas two years after DC the average was 0.4 ± 0.5 hospitalizations per patient (p = 0.002).

Data concerning ventricular function evaluation (echocardiography, radioisotopes), and functional capacity (FC, 6-minute walking test, oxygen consumption) are shown in Table 1.

This technique should be performed with low morbimortality to justify its insertion in the habitual practice. It must be remembered that this surgery provides benefits after a long period of time and involves patients with advanced CHF that have to be subjected to surgery. The total death rate during surgery and follow-up should be smaller than the number of deaths occurred with pharmacological treatment. The right choice of patients as well as the consideration of the technical aspects mentioned above help to achieve low morbi-mortality.

Although there was morbidity in this group, it was overcome satisfactorily. Mortality during postoperative period was 6.6%.

Functional capacity

FC improvement was observed one year after the operation with significant results. The preoperative value changed from 3.06 ± 0.2 to 1.8 ± 0.6. The FC improvement was kept after two years with a value of 1.7 ± 0.6 (p < 0.0001). This symptomatic recovery was observed during the 6-minute walking test, from 332 meters ± 127 in the preoperative period to 421 meters ± 102 after two years (p = 0.019). One important fact coincided with the FC improvement: there was an

important reduction in the number of hospitalizations, from 2.2 ± 0.7 patients/year, recorded one year before surgery to 0.4 ± 0.5 two years after it (p = 0.002).

Ventricular function

In the analysed patients as well as in other studies previously published, an important improvement in ventricular function was observed one year after DC; LVEF increased significantly from 23.6% ± 3 to 28% ± 2 one year after surgery and FS grew from 15.6% ± 4 to 18% ± 4 over the same period.

Values two years after the operation showed an LVEF of 29.7% ± 5 (p = 0.001) and an FS of 20.6% ± 5 (p = 0.003). This showed a trend to keep improvement of parameters achieved one year after surgery. Ventricular function and functional capacity were better compared to preoperative data.

With regard to LVDD, the values obtained one year after the operation did not decrease compared to the preoperative period. They ranged from 72.7 mm ± 3 to 73.6 mm ± 7. Ventricular diameter did not progress in its dilatation, although this was observed two years after surgery with a diameter of 72.3 mm ± 8 (NS).

The group of patients studied in this report shows FC and echocardiographic parameters similar to those reported in previous investigations. However, our patients had higher preoperative averages (23.6%) of LVEF compared to the statistics reported by Carpentier and Chachques (16%) and Moreira [5, 15] (19.8%). In addition the age average of our group was much more higher (59.2 years) in relation to the other mentioned series: 50 years and 48.2 years respectively. This point should be taken into account because in this pathology, the higher the average age, the greater the chances of morbi-mortality during the operative period [18, 19, 20].

Another point to be considered during follow-up is the observation of a certain reduction of the left atrial

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diameter. Values ranged from $55.5 \text{ mm} \pm 10$ during the preoperative period to $53.2 \text{ mm} \pm 10$ two years after surgery. Although the statistical trend is $p = 0.07$, a desirable sequence could be inferred considering a controlled ventricular diameter progression, a decrease in mitral ring diameter and an improvement in diastolic function.

It is not the purpose of this report to discuss experimental developments or physiological assumptions. Only the interpretation of data obtained in the clinical stage will be analysed here. Thus, from 15 patients submitted to DC 12 patients (80%) survived for a minimum period of two years. Two patients died, and this percentage represents a good result in relation to FC III patients under exclusive medical treatment [15]. It must be remembered that this group of DC subjects accumulated an average of 31.3 months, whereas Moreira reported only a 73% survival rate for patients under exclusive medical therapy during a period of 2 years [15].

In patients with a severe functional class the use of this technique can help to achieve a higher survival rate and a better quality of life. However, inclusion parameters must be respected, there must be a strict preservation of the muscle during its manipulation and stimulation, and a proper control must be kept during follow-up [6, 13]. The results obtained in this experience concerning ventricular function and evaluation of FC showed a considerable improvement compared to preoperative data. DC had proved to be a technique capable of being applied to CHF patients.

Aortomyoplasty

Dynamic Aortomyoplasty has been used in the last few years, for severe congestive heart failure treatment [2, 8]. Our clinical experience, with this method, is in ascending aorta [25, 26].

Regarding the inclusion criteria of patients, they were: dilated cardiomyopathy, NYHA FC III-IV, age up to 70 years, left ventricular ejection fraction up to 30%, oxygen consumption between 10 to 20 milliliters/kilograms/minutes, informed patient consent, contraindication for other therapies.

The exclusion criteria were: aortic valve insufficiency, aortic calcification, aortic aneurysm, systemic diastolic pressure up to 80 millimeters Hg with medication, Marfan syndrome.

Our population in aortomyoplasty includes six patients (five males). The etiology of dilated cardiomyopathy was: three Chagas's disease, two idiopathic cardiomyopathy and ischemic-necrotic the other.

In our preliminary experience these patients had contraindications for heart transplant (patient refusal, Chagas's disease, inadequate social environment) and contraindications for cardiomyoplasty (severe mitral/tricuspid regurgitation, severe cardiomegaly).

When analysing patients' characteristics we observed that: the mean age was 52 years with a range from 44 to 65, the FC mean was 3.1. Data concerning ventricular function evaluation and functional capacity are shown in Table 2.

Aortomyoplasty technique was done by two incisions. Last three patients were operated with ministernotomy approach. The incision was of 8 centimeters. In these cases the myocardial electrode was placed endovenously in right ventricle.

A cardiomyostimulator Transform was implanted in the six patients. The stimulus could coincide with the closing of the aorta valve checked by echocardiography.

At the moment, the extent of aortic diastolic augmentation is measured by the subendocardial viability index: diastolic pressure-time index/systolic tension-time index. Recently in common work with Dr Cabrera Fischer, we have developed a non-invasive test

Table 2

	Preoperative	Postoperative	p
FC (N.Y.H.A.)	3.25 ± 0.501	1.5 ± 0.58	$= 0.035$
Walking Test (m)	362 ± 54	473 ± 50	$= 0.008$
VO_2 (ml/Kg/m)	12.7 ± 4.8	16.1 ± 5.09	NS
LVEF (%)	19.5 ± 6.5	34.2 ± 15.8	$= 0.054 *$
LVDD (mm)	79.7 ± 13.6	74 ± 9.8	NS
RVDD (mm)	32.7 ± 8.7	23.2 ± 4.1	$= 0.063 *$
FS (%)	12.7 ± 6.7	20.7 ± 6.5	$= 0.026$
LAD (mm)	55.5 ± 5.2	48.2 ± 4.6	$= 0.064 *$
C/T Ratio	0.61 ± 0.01	0.58 ± 0.02	$= 0.035$
Hosp/y/p	4.25 ± 1.2	0.25 ± 0.50	$= 0.011$

FC: functional class; VO_2 : oxygen consumption; LVEF: left ventricular ejection fraction; LVDD: left ventricular diastolic diameter; RVDD: right ventricular diastolic diameter; FS: fractional shortening; LAD: left atrial diameter; CIT Ratio: cardiothoracic ratio; Hosp/y/p: Hospitalizations/year/patient; NS: not significative; * trend.

to indicate diastolic augmentation changes in patients with Aortomyoplasty. This work is based in the digital pressure signal with the Finapres.

In the follow-up one patient died at two months postoperative prior to full muscle conditioning (Arrhythmia).

Five patients alive at average of 13.2 months per patient.

- the full muscle conditioning was achieved in all five subjects;
- they are in New York Heart Association Functional Class I-II, and postoperative hospitalizations/year/patient was 0.2.

Summary of the results at average of 15 months postoperative with Aortomyoplasty in four patients with long-term follow-up is shown in Table 2.

Functional class improvement was observed. The preoperative value changed from 3.2 to 1.5. The symptomatic improvement is shown in the walking test, indicating that the patient improve their functional capacity. The oxygen consumption was incremented from 12 to 16 ml/kg/m. A significant improvement in fractional shortening correlates with the radionuclide ejection fraction which increase from 22% to 34%. When comparing baseline echo data to follow-up, no significant changes in the left ventricular end diastolic diameter were found. However, ventricular diameter did not progress in its dilatation. The right ventricular end diastolic diameter decreased, and the cardio/thoracic ratio showed a significant reduction.

Another point to be considered during follow-up is the observation of a certain reduction of the left atrial diameter. This improvement correlates with a decrease in tricuspid and mitral regurgitation.

There was an important reduction in the number of hospitalizations, from 4/patients/year, recorded 1 year before surgery to 0.2 15 months average after it. Moreover, the specific medication used in these patients tended to decrease significantly. These two circumstances are important because they represent objective considerations related to medical observation.

In conclusion: 1) aortomyoplasty has a sound conceptual basis; 2) this technique is feasible in patients with congestive heart failure; 3) preliminary short term results are encouraging; 4) present indications and contraindications are provisional and should be reviewed in the light of future research.

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