ORIGINAL PAPER

New Graduated Pressure Regimen for External Counterpulsation Reduces Mortality and Improves Outcomes in Congestive Heart Failure: A Report From the Cardiomedics External Counterpulsation Patient Registry

External counterpulsation (ECP) has been shown to increase exercise tolerance and reduce angina episodes, Canadian Cardiovascular Society Functional (CCSF) class, anginal medication usage, and hospitalizations in refractive CCSF class III and IV stable angina. However, the high pressures and resulting 1.5:1–2:1 peak diastolic to peak systolic pressure (D/S) ratios shown to be optimal in the treatment of angina can cause excessive preload and adverse effects in congestive heart failure (CHF) patients, particularly those with left ventricular ejection fractions <40%. Data were retrospectively analyzed from the Cardiomedics ECP Registry on 127 New York Heart Association (NYHA) class II–IV CHF patients (79.6% men; average age ± SD, 68.2±15.6 years), with a comorbidity of CCSF class III–IV refractive angina, who were serially treated with 35 hours of ECP (1 h/d, 5 d/wk for 7 weeks) at unconventionally low pressures and D/S ratios under a new graduated pressure regimen. The pressures and D/S ratios were gradually increased in stages over the 7-week ECP regimen. The patients were divided into three groups based on the pressures applied and the resulting average D/S ratios (Low, Mid, and High). In the Low D/S ratio group (average D/S ratio 0.7:1), all-cause mortality in the year following ECP treatment was only 1.85% (one of 54 patients), whereas over the same time period in the Mid D/S ratio group (average D/S ratio 1.08:1), all-cause mortality was 7.69% (three of 39 patients) and in the High D/S ratio group (average D/S ratio 1.32:1), all-cause mortality was 8.82% (three of 34 patients). For the Low, Mid, and High D/S ratio groups, respectively: 1) average left ventricular ejection fractions increased 23.0%, 20.1%, and 17.5%; 2) NYHA class declined 36.6%, 29.6%, and 29.6%; and 3) all-cause hospitalizations, including terminal admissions, were reduced 85.7%, 82.6%, and 57.1% in the year following ECP therapy from the prior year. There were no adverse effects or withdrawals from the ECP therapy and no significant difference in sex-based outcomes. Consequently, ECP applied at low pressures and average D/S ratios of 0.7:1 under the new graduated pressure regimen is safe and effective in the treatment of CHF and produces a significant reduction in mortality, compared with the 8.5% annualized mortality of the Multicenter Automatic Defibrillator Implantation Trial II (MADIT II) (N=1232) of NYHA class II–III CHF and the 12.2% annual mortality of the Comparison of Medical Therapy, Pacing, and Defibrillation in Heart Failure (COMPANION) study (N=595) of NYHA class III–IV CHF. Lower pressures improve patient comfort and may encourage more CHF patients to seek treatment. The reduction in hospitalizations should significantly reduce the cost of treating CHF. (CHF. 2005;11:147–152) ©2005 CHF, Inc.

External counterpulsation (ECP) is a noninvasive version of the intra-aortic balloon pump. However, the ECP device used in this study moves a significantly larger volume of blood than an intra-aortic balloon pump. ECP decreases cardiac workload while increasing myocardial perfusion pressure and cardiac output. The use of ECP for the outpatient treatment of angina pectoris has been shown to reduce the frequency of chest pain episodes, increase exercise tolerance, reduce the incidence of hospitalization, and reduce Canadian Cardiovascular Society Functional (CCSF) class in intractable angina.[1]

Cardiovascular hemodynamics would ordinarily indicate that congestive heart failure (CHF) patients with a left ventricular ejection fraction

Krishnaswami Vijayaraghavan, MD;[1] Lawrence Santora, MD;[2] Joel Kahn, MD;[3] Norman Abbott, MD;[4] Julius Torelli, MD;[5] Gil Vardi, MD[6]
From the Scottsdale Cardiovascular Center, Scottsdale, AZ;[1] Orange County Heart Institute, Orange, CA;[2] Michigan Heart Group, Troy, MI;[3] Palms Heart Center, Tarpon Springs, FL;[4] Integrative Cardiology Center, High Point, NC;[5] and St. Louis Heart and Vascular, St. Louis, MO[6]
Address for correspondence: Krishnaswami Vijayaraghavan, MD, Scottsdale Cardiovascular Center, 3099 Civic Center Plaza, Scottsdale, AZ 85251.
E-mail: kvijay@scresearch.org
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(LVEF) <40% would be less likely to benefit from ECP and, if treated with ECP, might be expected to experience an exacerbation of heart failure symptoms, as ECP compresses the venous beds in the lower extremities, increasing venous return (preload). Increased preload, particularly in CHF patients with an LVEF <40%, could potentially cause adverse events, including worsening of pulmonary heart failure,[2] increased morbidity and mortality,[3,4] and premature withdrawal from ECP therapy.[5] However, little data are available on the long-term effects of ECP—applied at unconventionally low peak diastolic to peak systolic pressure (D/S) ratios which are gradually increased—in the treatment of CHF.

Objective

This study seeks to analyze the effects of 35 1-hour ECP treatments applied at lower than customary D/S ratio levels in graduated stages over a period of 7 weeks, compared with conventional ECP D/S ratio levels, on mortality, LVEF, New York Heart Association (NYHA) CHF class and the incidence of all-cause hospitalization over a period of 1 year, compared with baseline and prior year data.

Methods

Study Population. The Cardiomedics ECP Patient Registry is a compendium of data on all patients undergoing ECP at the reporting sites. Data from this registry on a series of 127 NYHA class II–IV CHF patients with a comorbidity of CCSF class III–IV angina, consecutively treated with ECP at six clinical sites in the United States, were retrospectively analyzed. Patients were enrolled in the registry if they met the inclusion criteria: 1) between 20 and 80 years of age; 2) documented evidence of coronary artery disease; 3) coronary arteries not amenable to further percutaneous or surgical revascularization; 4) symptoms of intractable angina with inadequate response to medical therapy; and 5) symptoms and signs of CHF with shortness of breath, leg edema, or significant fatigue.

All patients received medical therapy consistent with conventional clinical practice, and 35 1-hour ECP treatments with the CardiAssist ECP System (Cardiomedics, Inc., Irvine, CA) for 1 h/d, 5 d/wk over a period of 7 weeks. One-year follow-up data were collected on all patients.

The 127 CHF patients were divided into three groups based upon the pressures applied in stages during the 35 1-hour ECP treatments and their resulting average D/S ratios. Pressures and D/S ratios were applied at uncommonly low levels (starting as low as 0.1:1), based on the patient's LVEF and response to ECP, and gradually increased in small increments in stages over the 35-hour, 7-week ECP regimen, under a new "Graduated Pressure Regimen" (patent pending) developed by the manufacturer of the ECP System used in this study.

The 54 CHF patients in the Low D/S ratio group were treated at an average D/S ratio of 0.7:1 (range 0.40:1–0.99:1) over the 7-week ECP regimen. The 39 CHF patients in the Mid D/S ratio group were treated at an average D/S ratio of 1.08:1 (range 1.00:1–1.29:1) over the same period. The 34 CHF patients in the High D/S ratio group were treated at an average D/S ratio of 1.32:1 (range 1.30:1–1.60:1) over this period, which is comparable to the D/S ratios commonly used in the treatment of angina.

Study End Points. The study end points were comparative changes in mortality, LVEF, NYHA CHF class, and incidence of all-cause hospitalizations (including terminal hospitalizations) of the three groups during a period of 1 year following ECP therapy, compared with baseline and the 1-year period preceding ECP therapy.

Statistical Analysis. Data on enrolled patients were collected at six clinical sites and entered into a standardized Excel database (Microsoft Corporation, Redmore, WA). The final dataset was merged and transferred to an SPSS 12.0 statistical package (SPSS Inc., Chicago, IL). Data were analyzed on each group of CHF patients and comparisons made pretreatment and 1-year post-treatment. Measurements were expressed as mean ± SD. Individual variable differences were determined using the Student *t* test for numerical variables and the chi-square test for categorical variables, with significance at $p<0.05$.

Baseline Data. Baseline characteristics of the three groups are shown in Table I. Of the 54 CHF patients in the Low D/S ratio group, 79.6% were men, and the mean age was 68.2±15.6 years. Six (11.1%) had class II CHF, 42 (77.8%) had class III CHF, and six (11.1%) had class IV CHF. CCSF class III angina was present in 76.8%, and 24.3% also had CCSF class IV angina. Mean LVEF before ECP therapy was 32.6%±7%. History of coronary artery bypass graft surgery was present in 75.9% and history of percutaneous transluminal coronary angioplasty was present in 90.7%.

Of the 39 CHF patients in the Mid D/S ratio group, 79.5% were men, and the mean age was 69.7±18.6 years. Nine (22.5%) had class II CHF, 24 (60.0%) had class III CHF, and six (15.0%) had class IV CHF. CCSF class III angina was present in 79.8%, and 14.3% also had CCSF class IV angina. Mean LVEF before ECP therapy was 31.3%±11%. History of coronary artery bypass graft surgery was present in 69.6% and history of percutaneous transluminal coronary angioplasty was present in 83.4%.

Of the 34 CHF patients in the High D/S ratio group, 82.4% were men, and the mean age was 69.7±22.4 years. Thirteen (36.1%) had class II CHF, 15 (41.6%) had class III CHF, and six (16.6%) had class IV CHF. CCSF class III angina was present in 74.5%, and 19.3% also had CCSF class IV angina. Mean LVEF before ECP therapy was 32.6%±20%. History of coronary artery bypass graft surgery was present in 78.9% and history of percutaneous transluminal coronary angioplasty was present in 80.9%.

The patients in all three groups received medical therapy in accordance with accepted medical practice.

Table I. Baseline Patient Characteristics by Study Groups

Characteristic	Study Group		
	Low D/S Ratio (n=54)	Mid D/S Ratio (n=39)	High D/S Ratio (n=34)
Average age (yr ± SD)	68.2±15.6	69.7±18.6	69.7±22.4
Men (n [%])	43 (79.6)	31 (79.5)	28 (82.4)
Women (n [%])	11 (20.3)	8 (20.0)	6 (17.6)
History of CABG (%)	75.9	69.6	78.9
History of PTCA (%)	90.7	83.4	80.9
Ejection fraction (% ± SD)	33±7	31±11	33±20
NYHA CHF class II (n [%])	6 (11.1)	9 (22.5)	13 (36.1)
NYHA CHF class III (n [%])	42 (77.87)	24 (60.0)	15 (41.6)
NYHA CHF class IV (n [%])	6 (11.1)	6 (15.0)	6 (16.6)
Angiotensin-converting enzyme inhibitors (%)	81.5	55.0	74.4
Beta blockers (%)	31.4	30.3	23.3
Diuretics (%)	68.5	55.0	75.0
Calcium channel blockers (%)	11.1	15.2	9.3
Nitroglycerin (%)	66.3	62.4	61.2

D/S=peak diastolic to peak systolic pressure; CABG=coronary artery bypass graft surgery; PTCA=percutaneous transluminal coronary angioplasty; NYHA=New York Heart Association; CHF=congestive heart failure

Table II. Mortality: Comparisons Between Groups

Study Group (NYHA class)	Mortality (%)	Comparison Group (NYHA Class)	Mortality (%)	*p* Value
Low D/S ratio (II–III)	0.00	MADIT II (II–III)	8.50	<0.0001
Low D/S ratio (III–IV)	2.10	COMPANION (III–IV)	12.20	<0.0001
Low D/S ratio (II–IV)	1.85	Mid D/S (II–IV)	7.69	<0.0001
Low D/S ratio (II–IV)	1.85	High D/S (II–IV)	8.82	<0.0001
Mid D/S ratio (II–IV)	7.50	High D/S (II–IV)	8.33	NS

NYHA=New York Heart Association; D/S=peak diastolic to peak systolic pressure; MADIT II=Multicenter Automatic Defibrillator Implantation Trial II study[6]; COMPANION=Comparison of Medical Therapy, Pacing, and Defibrillation in Heart Failure study[7]; NS=not significant

None of the 127 patients had an LVEF >40% or <20% (Table I).

Outcomes

Mortality. In the year following completion of ECP therapy, of the 54 CHF patients in the Low D/S ratio group (average D/S ratio 0.70:1), one class IV patient (1.85%) died at age 67 of CHF. Of the 39 CHF patients in the Mid D/S ratio group (average D/S ratio 1.08:1), three patients (7.69%) died (one class III and two class IV) at ages 62, 66, and 75 of CHF, cardiogenic shock, and sepsis, respectively. Of the 34 CHF patients in the High D/S ratio group (average D/S ratio 1.32:1), three class IV patients (8.82%) died at ages 49, 66, and 76 of cardiogenic shock, cardiogenic shock, and sepsis, respectively.

Of the 48 NYHA class II–III CHF patients in the Low D/S ratio group, none (0%) died in the year following ECP therapy, compared with the 8.5% mortality (adjusted to a 1-year period) reported in the Multicenter Automatic Defibrillator Implantation Trial II (MADIT II)[6] of an implantable defibrillator in the treatment of 1232 NYHA class II and III CHF patients ($p<0.0001$). Of the 48 NYHA class III–IV CHF patients in the Low D/S ratio group, one (2.1%) died in the year following ECP therapy, an 82.8% reduction ($p<0.0001$) from the 12.2% 1-year, all-cause mortality reported in the Comparison of Medical Therapy, Pacing, and Defibrillation in Heart Failure (COMPANION) study[7] of 595 NYHA class III–IV CHF patients treated with a dual chamber pacemaker with or without an implantable defibrillator.

The 1.85% annual mortality in the 54 patients in the Low D/S ratio group was a 75.3% reduction from the one year mortality of 7.69% in the Mid D/S ratio group ($p<0.001$) and a 77.8% reduction from the 8.82% 1-year mortality in the High D/S ratio group ($p<0.0001$).

There was no statistical difference in annual mortality between the Mid and High D/S ratio groups (Table II).

Ejection Fraction. LVEF was assessed by echocardiography before and 1 year after ECP treatment. Of the 53, 36, and 31 surviving patients in the Low, Mid, and High D/S ratio groups and the 123 surviving patients of the group as a whole, LVEFs improved by 23.0%, 20.1%, 17.5%, and 20.4%, respectively, one year after ECP therapy, from a mean of 32.6% to 40.1%, 31.3% to 37.5%, 32.6% to 38.3%, and 32.3% to 38.9%, respectively (Table III).

Table III. Left Ventricular Ejection Fractions of Surviving Patients

Group	Before ECP (%)	Year After ECP (%)	Change (%)	p Value
Low D/S ratio (n=53)	32.6±7.2	40.1±26.9	+23.0	<0.05
Mid D/S ratio (n=36)	31.3±11.6	37.5±27.5	+20.1	NS
High D/S ratio (n=31)	32.6±20.4	38.3±14.7	+17.5	NS

ECP=external counterpulsation; D/S=peak diastolic to peak systolic pressure; NS=not significant

Table IV. New York Heart Association Congestive Heart Failure Classification of Surviving Patients

Group	Before ECP	Year After ECP	Change (%)	p Value
Low D/S ratio (n=53)	3.0±1.0	1.9±0.5	–36.6	<0.0001
Mid D/S ratio (n=36)	2.7±1.3	1.9±0.5	–29.6	<0.005
High D/S ratio (n=31)	2.7±1.3	1.9±0.5	–29.6	<0.01

ECP=external counterpulsation; D/S=peak diastolic to peak systolic pressure

Table V. Annual Average Number of All-Cause Hospital Admissions Per Patient

Group	Year Before ECP	Year After ECP	Change (%)	p Value
Low D/S ratio (n=54)	2.8±1.6	0.35±0.5	–87.5	<0.0001
Mid D/S ratio (n=39)	2.5±1.4	0.42±0.5	–83.2	<0.0001
High D/S ratio (n=34)	1.3±1.7	0.70±0.5	–46.2	<0.01

ECP=external counterpulsation; D/S=peak diastolic to peak systolic pressure

NYHA CHF Class. Of the 53 surviving patients in the Low D/S ratio group, NYHA class improved by an average of 36.6% from a mean class of 3.0±1.0 pretreatment to a mean class of 1.9±0.5 1 year after ECP treatment ($p<0.0001$). Of the 36 surviving patients in the Mid D/S ratio group, NYHA class improved by an average of 29.6% from a mean class of 2.7±1.3 pretreatment to a mean class of 1.9±0.5 1 year after ECP treatment ($p<0.005$). Of the 31 surviving patients in the High D/S ratio group, NYHA class improved by an average of 29.6% from a mean class of 2.7±1.3 pretreatment to a mean class of 1.9±0.5 1 year after ECP treatment ($p<0.01$) (Table IV).

Hospitalizations. Of the 54 Low D/S ratio group patients, the average incidence of all-cause hospitalization, including terminal hospitalizations, was reduced by 87.5% from a mean admission rate of 2.8 per patient in the year before ECP treatment to 0.35 per patient in the following year ($p<0.0001$). Of the 39 Mid D/S ratio group patients, the average incidence of all-cause hospitalization, including terminal hospitalizations, was reduced by 83.2% from a mean admission rate of 2.5 per patient in the year before ECP treatment to 0.42 per patient in the following year ($p<0.0001$). Of the 34 High D/S ratio group patients, the average incidence of all-cause hospitalization, including terminal hospitalizations, was reduced by 46.2% from a mean admission rate of 1.3 per patient in the year before ECP treatment to 0.7 per patient in the following year ($p<0.01$) (Table V).

As seen in Table IV, the incidence of hospitalization was significantly reduced in all NYHA CHF classes in both the Low D/S ratio and Mid D/S ratio groups in the year following ECP therapy, compared to baseline ($p<0.0001$). However, in the High D/S ratio group, the change in NYHA CHF class was not significant in CHF Class II and was less significantly improved in the Class III and IV CHF patients ($p<0.0001$).

Sex-Based Differences. While mortality in the year following ECP therapy in women was 7.7% (1 of 13) and 14.3% (1 of 7) in the Low D/S ratio and Mid D/S ratio groups, respectively, compared to mortality in men of 0.0% (0 of 41) and 6.3% (2 of 32), in the High D/S ratio group, mortality in men was 6.9% (2 of 29) vs. mortality in women of 0.0% (0 of 5) in the year following ECP therapy. No assessment of statistical significance was performed due to the small samples and disparity in population sizes. There were no significant sex-based differences in LVEFs, NYHA CHF class, or incidence of hospital admissions (Table VII).

Discussion

ECP is a noninvasive, nonpharmacologic therapy that has been shown to be of benefit in reducing the number of anginal episodes, exercise-induced myocardial ischemia, CCSF class, and incidence of hospitalization in patients with chronic stable angina.[1] However, due to concern over the increased preload resulting from ECP and its potential to worsen heart failure symptoms in patients with CHF,[2–5] particularly those with LVEFs <40%, data on the use of ECP in the treatment of patients with left ventricular dysfunction is sparse.

In previous studies,[2–5] CHF patients treated with an ECP device (EECP, Vasomedical, Inc., Westbury, NY) were shown to be more likely to experience an adverse cardiac event, less

Table VI. Average Number of All-Cause Hospitalizations by New York Heart Association (NYHA) Class

Group	NYHA Class	n	Hospitalizations Year Before ECP	Hospitalizations Year After ECP	Change (%)	p Value
Low D/S ratio	II	6	1.33	0.17	–88.5	<0.0154
	III	42	3.08	0.38	–87.8	<0.0001
	IV	6	2.38	0.38	–84.0	<0.0154
Mid D/S ratio	II	6	1.78	0.11	–94.4	NS
	III	24	2.46	0.46	–81.4	<0.0001
	IV	9	2.33	0.50	–78.6	<0.005
High D/S ratio	II	13	1.0	0.85	–15.0	NS
	III	14	0.79	0.36	–54.5	<0.01
	IV	7	2.9	0.9	–68.9	NS

ECP=external counterpulsation; D/S=peak diastolic to peak systolic pressure; NS=not significant

Table VII. Sex-Based Differences

Group	Average Age (yr)	Mortality (% [n])	LVEF Change (%)	NYHA Change (%)	Hospitalization Change (%)
Low D/S ratio					
Men (n=41)	68.5	0.0 (0)	+24.1	–26.6	–85.5
Women (n=13)	65.2	7.7 (1)	+20.8	–25.8	–87.3
Mid D/S ratio					
Men (n=32)	68.9	6.3 (2)	+16.8	–24.1	–80.8
Women (n=7)	74.9	14.3 (1)	+22.2	–34.5	–94.2
High D/S ratio					
Men (n=29)	70.7	6.9 (2)	+20.2	–32.1	–50.0
Women (n=5)	66.4	0.0 (0)	+15.4	–33.3	–55.6

LVEF=left ventricular ejection fraction; NYHA=New York Heart Association; D/S=peak diastolic to peak systolic pressure

likely to benefit from ECP, have a higher likelihood of morbidity and mortality, and were more likely to prematurely withdraw from the 35-hour 7-week ECP treatment regimen. Exacerbation of CHF symptoms was the most frequent reason for non-completion of the ECP regimen.

The present study is the first to report a significant reduction in all-cause mortality in NYHA class II–IV CHF patients in the year following 35 1-hour ECP treatments over a period of 7 weeks, under a new, graduated pressure regimen, starting at D/S ratios as low as 0.1:1. Incremental increases in pressures and D/S ratios were made in stages during the 35-hour course of therapy. The average D/S ratios over the 35-hour course of ECP therapy under the new regimen in the Low and Mid D/S ratio groups were substantially lower than D/S ratios commonly used in the treatment of angina.

One-year all-cause mortality in the 48 NYHA class II–III CHF patients in the Low D/S group was zero, compared with the adjusted annual mortality of 8.5% in the 1232 NYHA class II–III CHF patients of the MADIT II study[6] of an implantable defibrillator. One-year all-cause mortality in the 48 NYHA class III–IV CHF patients in the Low D/S ratio group was 2.1%, an 82.8% reduction from the 12.2% annual all-cause mortality in the 595 NYHA class III–IV CHF patients in the COMPANION study[7] of a dual chamber pacemaker with or without an implantable defibrillator.

One-year all-cause mortality of 1.85% in the Low D/S ratio group (average D/S ratio 0.7:1) was 75.33% lower than the 1-year all-cause mortality of 7.50% in the Mid D/S ratio group (average D/S ratio 1.08:1) and 77.8% less than the 1-year, all-cause mortality of 8.33% in the High D/S ratio group (average D/S ratio 1.32:1).

While the present study is small compared with the very large population of NYHA class II–IV CHF patients addressed in the American Heart Association's Heart Failure and Stroke 2002 Statistical Update,[8] the 1.85% 1-year mortality in the Low D/S ratio group was 90% lower than the historical 18.8% annual mortality from CHF reported in the 2002 Statistical Update, which included NYHA class I patients, who typically experience little or no mortality.

In addition, at 1 year, there was a significant increase from baseline in mean LVEFs and a significant reduction from baseline in mean NYHA CHF class, as well as a significant reduction in the average incidence of hospital admissions in the year following ECP treatment, compared with the year before ECP. The Low D/S ratio group had the greatest increase in LVEFs, reduction in CHF class, and decline in hospitalizations.

Mortality in women in this study (8.0%) was higher than in men (4.9%). However, the population sizes were small and of disparate sizes

(25 vs. 102). If these mortality rates are confirmed by a larger study, it may indicate the need for earlier and more aggressive ECP and medical therapy in women with CHF.

The safety of the ECP device used in this study is demonstrated by there having been no adverse events and no patient withdrawals during or following ECP therapy. The lower pressures employed to produce the Low D/S ratios increased patient comfort and made ECP more tolerable.

The benefits of ECP in the treatment of CHF noted in this study may be due to a variety of factors. In addition to the new graduated ECP regimen's theoretical potential to train the heart to accept and eject increasing volumes of blood and, perhaps, training the ventricles to beat more synchronously, improvement in endothelial function is believed to result from increased shear forces.[9] The release of endogenous growth factors[10] is thought to cause angiogenesis and increased vascularity of the myocardium. An increase in NO production[11] may potentially be another therapeutic effect. Other hypotheses for the efficacy of ECP include enhancement of vascular reactivity, neurohormonal alteration, stimulation of protein kinases, and alteration of myocyte metabolism at the cellular level.

The present study is limited in that it is a retrospective analysis with no control group, and the population is small. No efforts were made to maximize the use of neurohormonal blocking agents before enrollment. In spite of this, the average utilization of angiotensin-converting enzyme (ACE) inhibitors at baseline was 63.8% and β blockers 30.7% in this study population. It is possible that some of the NYHA class IV patients could not tolerate either of these agents, thus creating an opportunity to use ECP therapy as a bridge to initiate and/or up-titrate the administration of β blockers and ACE inhibitors, resulting in a reduction in mortality.

Other caveats to this study include the variability of subjective assessment of NYHA class, the variability of thresholds for hospitalization for CHF in different parts of the country, and interobserver variability of echocardiographic interpretations of LVEFs (±5%).

In spite of these limitations, the present study clearly demonstrates the significant benefits, efficacy, and safety of ECP administered at average D/S ratios of 0.7:1 in the treatment of CHF under the new graduated pressure regimen. While additional data from prospective, controlled clinical studies would be desirable, ethics may preclude randomization of CHF patients to a control group, in light of the reduction in mortality demonstrated in this study.

Conclusion

ECP, rendered under the new graduated pressure regimen utilized in this study at unconventionally low pressures and average D/S ratios of 0.7:1, is safe and efficacious in the treatment of CHF and significantly reduces mortality, increases LVEFs, improves CHF functional status, and reduces hospital admissions over a period of 1 year following completion of ECP therapy. The use of lower pressure under the new regimen increases the patient's ability to tolerate ECP therapy and could encourage more heart failure patients to be treated, and the reduction in hospital admittances could significantly lower the cost of treating CHF.

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